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SOME SIX-INCH METER TESTS AND HOW THEY WERE MADE.

BY FRANK C. KIMBALL, SUPERINTENDENT OF WATER WORKS, KNOXVILLE, TENN.

[*Presented September 10, 1903.*]

The Knoxville Water Company, through its treasurer, last winter, deeming it expedient to know the retardation or loss of pressure caused by 6-inch meters of certain types and makes, instructed the writer to investigate and report upon this subject as fully as possible. Interviews with various meter manufacturers and others, as well as an examination of such literature as might bear on this subject, disclosed the fact that with very few exceptions, no information upon the matter under discussion was available to the water works fraternity. The two most notable exceptions to this statement are the tests made by Mr. E. V. French in 1896 and 1897, of one 3-inch, six 4-inch, one 6-inch, and one 8-inch meter, some results of which were published in Volume XII, page 73, of the JOURNAL of this Association; and the testing of two 6-inch meters, incident to the testing of numerous fire hydrants, by Mr. Charles L. Newcomb, M. Am. Soc. M. E., at Holyoke, Mass., in 1897 and 1898, the results of which were published in Volume XX of the Transactions of that Society; and to these two valuable contributions on this subject I would recommend your careful attention. As, however, this information did not fully answer the requirements of our company, it

was thought desirable to make tests ourselves along these lines. With this end in view a letter was addressed in March last to all known meter manufacturers in the country, asking them to submit a 6-inch meter of each type made by them, the same to be subject to tests, including amongst others the following:

First. To determine the loss of head or retardation of flow by the passage through them of varying quantities of water, say from 25 cubic feet per minute to as large an amount as would flow under the conditions resulting, possibly as high as 300 to 400 cubic feet per minute in some types of meters.

Second. To determine how small a stream each meter would register, and with what per cent. of slip or leakage, or, in other words, what the unrecorded flow will amount to on various discharges, from the smallest stream possible to register, as well as their accuracy on various-sized streams up to their capacity.

It was also stated in the same letter of invitation that the results of such tests might be used in discussion before this or other associations, and for this reason we desired to have as many kinds of meters represented as possible.

Of the nine companies to whom this invitation was addressed, one replied that it made nothing larger than 2-inch meters, and therefore could not accept; two declined to send, while another agreed to send one, but failed to do so; leaving five who responded by sending nine different meters. As those submitted included four of the so-called rotary or piston type,—namely, the Hersey Rotary, the Crown, the Empire, and the Union; two of the disc type, the Hersey Disc and the Keystone of the Pittsburg Company; and three of the so-called current type, the Torrent, the Gem, and the Standard,—a sufficiently wide range of styles and kinds was tested to gain fairly good comparative results, so that from the data herewith submitted we may be assisted in selecting such type and style of meter as will best answer the particular purpose for which meters may be desired.

As, however, new types of meters are occasionally placed upon the market, and as meters already known are from time to time improved or claims made of improvements, and as for lack of testing and knowledge of them their adoption is a matter of uncertainty with water departments, it was assumed that this Association would be as much interested in the details of

the apparatus and the method of testing as in the results obtained, more particularly as the expense of installing a permanent testing plant for large meters is not great, comparatively speaking. By the installation of such testing plants in several of the larger cities within the limits of the members of this Association, there would result, in our opinion, a toning up, as it were, of the meter manufacturers to a more thorough consideration of the requirements of both water departments and insurance underwriters. There would also be a more potent incentive to manufacturers to turn out large-sized meters which would fulfill the requirements of close registration on both small and large streams, knowing that such meters would undergo the same care in testing as is now so generally given to the smaller, or house meters. In addition to this, such a system of tests would give the managers of water plants sufficient data to enable them to determine the selection of the meter best suited to the particular work it is do to, and to see, when it is received and before placing, that it would do it, and thus do away with that large amount of guesswork, now frequently indulged in, as to the capacity and performance of meters above 2 inches in size, to the disadvantage at times of both the water departments and consumers, neither being satisfied that they are not getting the worst end of the bargain. That there is uncertainty, even in the minds of meter manufacturers, as to just what their own meters in the larger sizes will do was particularly emphasized to the writer, when, in asking one of them how close a certain meter of his would register on certain-sized streams and how much retardation there would be in it under certain flows, the reply was made that, to his knowledge, but one meter company in the country was in position to make such tests with any degree of accuracy on large-sized meters; and, naturally supposing him to be referring to his own company, upon asking what company it was, the rather surprising answer was received that it was a competitor of his. Asking him then how he knew what his meters would do, the reply was that very careful experiments were made upon all sizes of meters up to and including 2-inch, and occasionally on 3- and 4-inch where possible, and from these the construction details of the larger sizes were designed and their effectiveness obtained by comparison. Assuming the above to be facts, a

more definite knowledge by water-works officials of what can or cannot be done by meters, which at the present time are purchased largely upon faith in the manufacturer, is a necessity, although I must not be understood as saying that any of the manufacturers would intentionally misstate the performance of their particular meters. On the contrary, I have more than once been informed by them, when asking for certain facts, that while they thought certain results would be attained, they could not positively guarantee that they would be; and their statements to me as a rule have been conservative rather than otherwise. For these reasons I do not hesitate to trespass upon your time to explain rather fully how these tests were made, in the hope that it will bring out discussion as to the needs of such testing apparatus and suggestions as to how the methods employed by us may be improved, with the further result that meter manufacturers or others may supply the trade with suitable apparatus for this purpose.

The first requisites for tests of this description are an adequate supply of water and facilities for quickly getting rid of it, as at times possibly a discharge of 2 500 to 3 000 gallons per minute or even more will be desired. The tests described were made at the river pumping station of the Knoxville Water Company, which is situated upon the northerly bank of the Tennessee River at Knoxville, Tenn., a general view of which is shown on Plate I. Reference to Fig. 1 will also show, in the lower left-hand corner, a general plan of the pumping station buildings, river bank, and intake tower. The water for these tests was obtained through the 14-inch main shown on that plan, this force main coming directly from the low-service reservoir of the company, which is about 2 625 feet from the point where the 6-inch wrought-iron pipe shown is taken off. This 6-inch pipe, which was laid expressly for this work, was 100 feet in length from its connection with the 14-inch main to piezometer ring "B" on Fig. 1. High-water line in the reservoir is at elevation 247.5, low-water line in the river being grade 10, and the general level of the testing apparatus, 53.5. During the progress of the tests the reservoir ranged from full to 4 feet out, making its average elevation about 245.5 and the average available static head 192 feet, or a little over 83 pounds pressure when no water

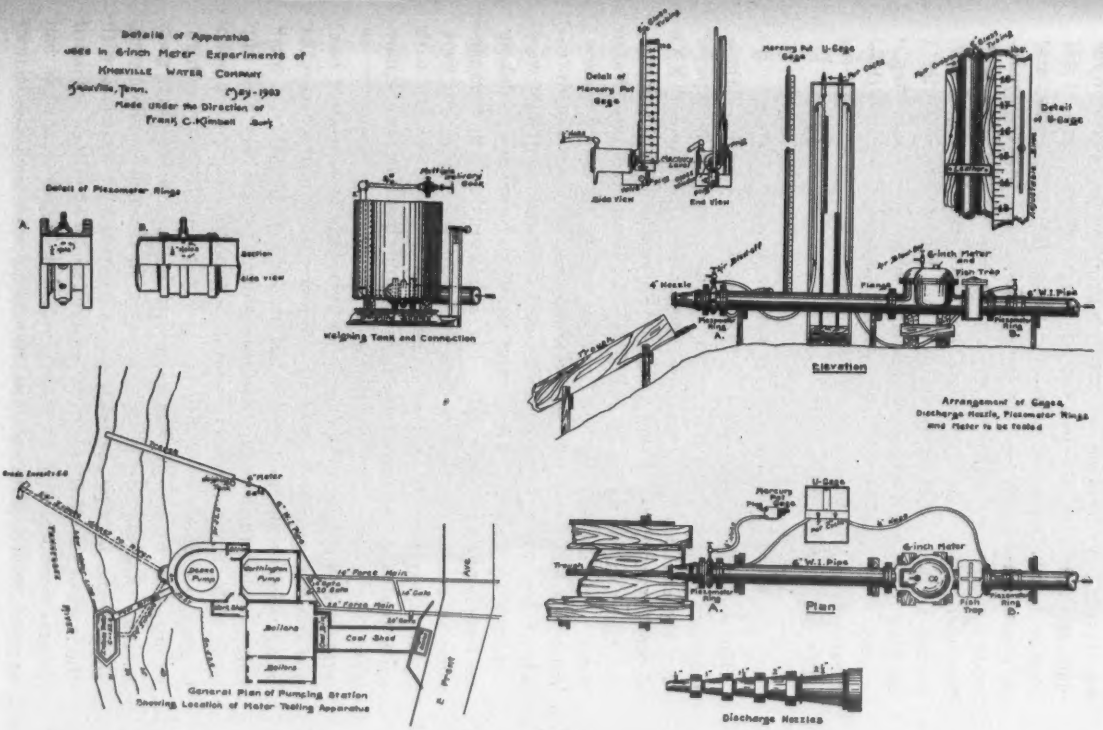
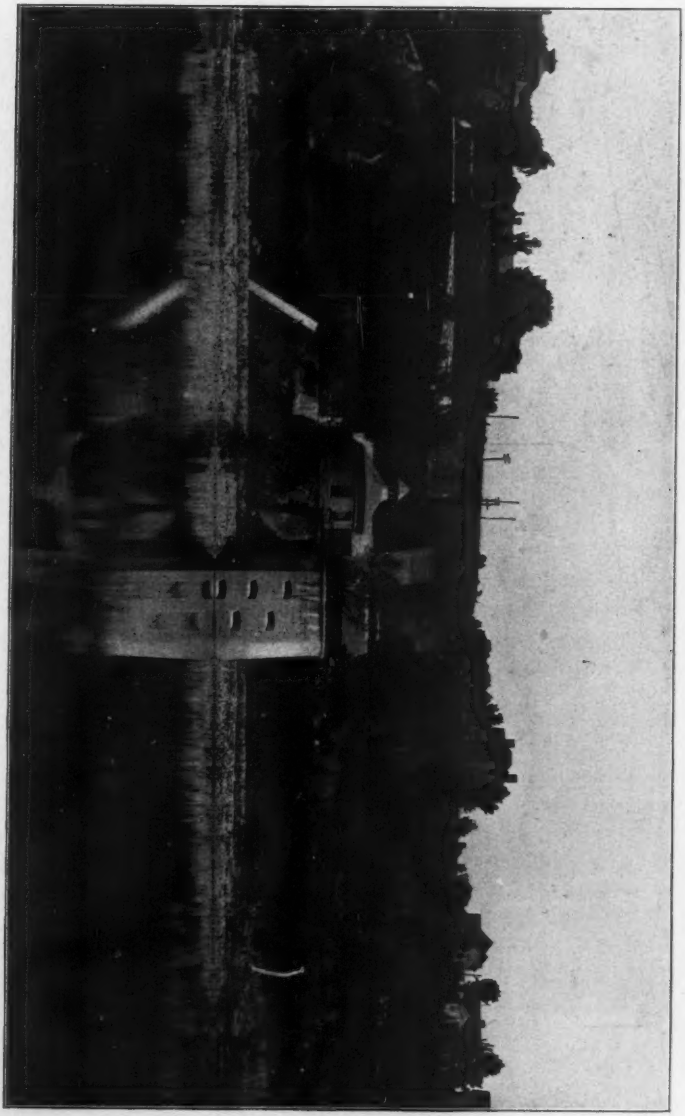

Details of Apparatus
used in 6-inch Meter Experiments of
KNOXVILLE WATER COMPANY
Knoxville, Tenn. 1903
Made under the Direction of
Frank C. Kimball, Supt.
Details of Piezometer Rings
Weighing Tank and Connection
Detail of Mercury Pot Gage
Mercury Pot Gage
U-Gage
Detail of U-Gage
Side View
End View
4" Hozzle
6" W.I. Pipe
6-inch Meter
Flange
Elevation
Arrangement of Gages, Discharge Nozzle, Piezometer Rings and Meter to be Tested
Pumping Station
Boilers
Coal Shed
General Plan of Pumping Station
Showing Location of Meter Testing Apparatus
Plan
Discharge Nozzles

FIG. 1.

was being drawn. This 14-inch main, being a reserve force main and not ordinarily used for pumping, and coming as it did directly from the reservoir, was well fitted for this purpose and gave pressures fairly free from vibrations and with comparatively small loss of head by friction under the heavier flows used. The water after passing through the meter was discharged into the air, an open trough shown both on Plate I and in Fig. 1 catching it as it fell from the discharge nozzle and conducting it into the river without washing the banks, although some of these streams were projected well into the river with very little of the water falling into the trough.

METHODS AND APPARATUS.

The general methods used in these nozzle tests followed those described by Mr. John R. Freeman in his very excellent paper on "Hydraulics of Fire Streams," as published in Volume XXI of the Transactions of the American Society of Civil Engineers, and those in his paper on "The Nozzle as an Accurate Water Meter," published in the Transactions of the same society, Volume XXIV, and to these valuable papers I am largely indebted for ways and methods used. Similar methods were employed by Mr. E. V. French and Mr. C. E. Newcomb in making the tests heretofore referred to. Fig. 1 shows in detail the arrangement of the apparatus. Measurements of water pressure were in all cases taken by means of an open mercury column with scale graduated to read directly in pounds pressure per square inch, the glass tube being about $\frac{5}{16}$ inch in diameter internally and $\frac{1}{2}$ outside. This tube, by means of a stuffing box, was connected to the outlet of the mercury cistern, this outlet being from the bottom of the cistern, and controlled by a small valve so that the mercury could be shut off if necessary at any time. The mercury cistern was an aluminum pot, rectangular in plan and about 4 by 5 inches in size by about 3 inches high, to one side of which was fastened the scaleboard and glass tubing. A small circular glass window in this side of the cistern allowed the zero of the scale to be compared at all times with the level of the mercury in the cistern, which level was compared several times daily and mercury added if from leakage any had escaped, which, however, was seldom. Two $\frac{1}{4}$-inch connections



RIVER PUMPING STATION, KNOXVILLE WATER CO., KNOXVILLE, TENN.

were in the top of the cistern, one of which had a short nipple, an elbow, and another nipple of ¼-inch pipe, to which stout rubber hose was attached by means of wire wrapping and twisting, which hose was then carried to piezometer ring " A." The other connection in the top of the cistern was used as an air valve, a ¼-inch valve being screwed into it and the air frequently blown out. This orifice was also used to add mercury as needed. As the pressure increased and the mercury in the cistern lowered, the height of the mercury column was also lowered, but to a very small amount. In graduating the scale, allowance was made for this, with the result that with cistern and glass tube of the sizes used, a mercury pound was 2.0382 inches, the height of a mercury column corresponding to one pound, per square inch pressure being 2.0452 inches at 60° F. As care was taken to set the zero of the scale at the same level as the outlet of the nozzles, pressures were read direct without correction for difference in level. Where it is not practicable to set the zero of the scale on the same level as the center of the discharging nozzle, it may be set at any level and correction made for the difference, which difference may be found either with an engineer's level or by filling the nozzle with water to its center and noting where it rises on the scale, this latter method, where possible, being the easier and less liable to error. The scale was graduated in pounds and tenths to eighty-seven pounds, being thus about 15 feet high, and to read it, a light ladder was attached to the framework, supporting it. The glass tubing was in two sections, joined together by a sleeve of rubber hose wrapped with wire and twisted tight. If care is taken in making the joints and connections, no trouble from leaks need be feared, although more care is required to make a joint tight against mercury than against water.

The retardation or loss of pressure in the meters was measured by means of a " U " gage, which is simply two glass tubes similar to the one used for measuring the pressure in the open column, connected together at the bottom and about half filled with mercury. Near the top of these tubes from a tee is taken off a hose connection on each side, one of which is connected to a piezometer ring back of the meter, shown on Fig. 1 as piezometer ring " B," and the other to a similar ring shown as piezometer ring " A." In the tops of there tubes are inserted

pet cocks, connected thereto by rubber hose sleeves wired tightly, these being used not only when water is first let into the gage, but at frequent intervals thereafter, to blow out any air that may have accumulated therein. In the gage shown here, sliding scales were used on each arm,one reading upward and the other down, the zero on both being carefully brought to the level of the two mercury columns when everything was at rest. Care in setting this gage at any particular height need not be taken, as it shows simply differences in pressures which will be the same regardless of the height of the gage itself; but the graduations of the scale to read pounds direct will be slightly different from those of the open column, as the weight of the column of water has to be taken into consideration as well as the mercury, and doing this will make the height of the mercury column under these conditions 2.2051 inches for one pound difference in pressure; in other words, for each 2.2051 inches difference between the height of mercury in the two tubes there is a loss of one pound pressure. If, therefore, the two scales are graduated for mercury pounds and tenths of a pound as above, and the top of one and bottom of the other are brought to a level with both columns of mercury with everything at rest, by reading simultaneously both scales on the gage when in operation, their sum will give the total loss of pressure or retardation between the piezometer rings.

Two piezometer rings should be used, one back of the meter to be tested and from 5 to 10 feet ahead of any gate, elbow, or other possible means of deflection of the current of water, and the other ahead of the meter and not less than the same distance from it, so that changes in direction of the water in passing through gates, elbows, meters, etc., will have time to substantially straighten out before reaching the piezometer rings, thus largely avoiding false readings incident to eddies and unequal pressure. On Fig. 1 are shown two different styles of piezometer rings, the one marked " A " being of cast iron, flanged, while the one marked " B " is of wrought iron and composition fitted for screw connections. In brief, any truly smooth piece of pipe, of practically exact diameter, surrounded on the outside with an annular ring, having three or more $\frac{1}{16}$- or $\frac{1}{8}$-inch holes drilled through into the pipe at equal distances apart, care being taken to have the orifices at right angles with the pipe, on circum-

ferential line, and without burrs or roughness on the inside of the pipe, will make a good piezometer ring. The reason for the use of such ring is that if, through any cause, the direction of the current of water is changed or impinges harder upon one side of the pipe than upon the other, the pressure within the annular ring, which is imparted to the water through the various orifices, will be equalized and correctly indicated. The same results for all practical purposes, perhaps, with care in drilling, can be obtained by drilling three or more holes directly into the pipe under the above conditions, and screwing in nipples, connecting them all together outside into one line, to which the hose running to the gages is connected; but as there is more liability of roughness under such arrangement, due to nipples or burrs projecting into the pipe, the use of regularly constructed rings is recommended. Into the annular ring above mentioned should be tapped one or more holes ¼-inch in size, into which nipples can be screwed and connections made with the gages by means of hose or otherwise. Between the nipples and the hose it is advisable to place a ¼-inch valve to regulate the flow to the gages, and this is also useful, where there is much vibration, to throttle the pulsations down as low as possible, although in so doing extreme care should be taken not to shut down too closely. Some movement in the mercury column should be noticeable at all times so as to be certain that there is a free opening to transmit the pressure. An air valve on the upper side of the piezometer rings will be of assistance in removing the air from the rings and preventing it getting into the mercury pot or tubes. In our apparatus, as shown, one leg of the " U " gage was connected to a tap in the top of piezometer ring " A " with a blow-off cock above it, while the open-end mercury gage was connected to another tap in the side of the same piezometer ring.

Among the most important parts of the apparatus needed, for discharges of thirty gallons per minute and upwards, are the nozzles, and, in the opinion of the writer, to have as high initial pressures as possible these should range in size of orifice from at least ½ inch to 4 inches, and under some conditions perhaps to 5 inches. The nozzles used in these tests were a 4-inch and a 2½-inch, kindly loaned us, with other apparatus, by the Factory Mutual Fire Insurance Companies of Boston, and a 2-inch, a 1½-

inch, a 1-inch, and a ½-inch which we had made for the purpose. These are all fitted with iron-pipe threads, so that one screwed on the next in size as shown. An additional nozzle of 3 inches in size would be useful in a permanent plant, although various rates of discharge can be obtained with any size nozzle by throttling the controlling gate back of the first piezometer ring. In the construction of these nozzles Mr. Freeman, in his article on "The Nozzle as an Accurate Water Meter," page 511, states the following requisites for good work:

"A smoothly tapering nozzle whose sides converge at an angle of somewhere between 5 and 7½° to the axis, and whose interior is smoothly polished for a distance back equal to, say, three or four times the diameter of the orifice."

Also, in speaking of using different-sized nozzles, one screwed on the other, substantially as shown on Fig. 1, herein, he says, page 512, *ibid.*:

"The smaller nozzles can be detached, leaving the larger ones in place, and thus securing an orifice of any desired size. Intermediate sizes can be attached to the same base, as, for instance, a 2½-inch could be screwed on to the end of the 3-inch in place of the 2-inch as shown [speaking of a sketch in his report]. The inside corner at the extreme end of each nozzle in the series should be rounded out to lessen the chance of bruising. A straight cylindrical tip of uniform diameter for a length equal to about half the diameter of nozzle is formed at the end of each, and the angle where this unites with the conical portion is smoothly rounded off."

These nozzles should be connected directly with the outer piezometer ring so that the pressures obtained by means of this ring will be practically those at the base of the nozzle. In all cases of either flanged or nipple connections of the various parts of the apparatus, care should be taken that gaskets do not project into the barrel of the pipe, and that all burrs and rough edges on nipples are removed so that no obstruction will be presented to the easy and straight flow of the water.

It is assumed that the nozzles have been carefully calibrated, and it is desirable, for use with a permanent plant, to construct discharge tables for each nozzle. For ordinary work, tables giving the discharge for each pound or half-pound pressure,

within the range of pressures that will be used, will be sufficient, and pressures between calculated points can be interpolated. Where considerable use is to be made of the nozzle determinations, time will be saved and more accurate results will be obtained by extending the table to include discharges for each tenth of a pound. This is as close, taking into consideration the vibrations of the mercury column, as pressures will probably be read, but when possible, by means of a vernier or by estimation, to read closer, interpolated discharges will be as accurate as can be desired. A more rapid but not as accurate way of obtaining quantities would be by calculating a sufficient number of discharges at various pressures to enable a curve to be constructed, either on ordinary or logarithmic cross-section paper, and the discharge read directly from such curves for the recorded pressure. The formula from which to determine such discharge is given by Mr. Freeman as follows:

$$G = \frac{29.83\ c\ d^2}{\sqrt{1 - c^2 \left(\frac{d}{D}\right)^4}} \sqrt{p}$$

Where G = gallons discharged per minute.

c = Coefficient of discharge of nozzle used.

d = diameter of orifice of discharge, in inches.

D = diameter of inside, or barrel, or piezometer ring, in inches.

p = indicated pressure in pounds per square inch at base of nozzle.

An inspection of this formula will show that where the diameter of the nozzle and piezometer rings are determined and the value of *c* fixed, the formula can be reduced to a constant, by which it is only necessary to multiply the square root of the pressure in pounds to obtain the discharge in gallons per minute. In this formula the only uncertain factor is the value of *c*, and this, with nozzles constructed as directed, Mr. Freeman has, through a very elaborate series of experiments, determined to be about .995. The smaller nozzles used by the writer, however, were not as smooth and regular as could be desired, and a series of experiments were made to determine what the coefficients of discharge of these particular nozzles were. The values of *c*, as so determined, as well as actual diameters of the nozzles used, are as follows:

Nominal Diameter, Inches.	*Actual Diameter, Inches.*	*Coefficient of Discharge = c.*
½	0.509	.965
1	1.048	.970
1½	1.503	.980
2	1.998	.990
2½	2.463	.995
4	3.954	.995

Future experiments, however, should be cautioned as regards using these particular coefficients, — except as to the last two, — as the writer firmly believes from results obtained that with nozzles constructed as directed, for all sizes from ½ inch up, the value of *c* will range from .990 to .995. Practice in experimental work of this kind, especially with two or more of the larger meters of standard makes, will soon enable one to so adjust this value as to bring all sized nozzles into a consistent relation one with the other, and also with the meters, after which such value may be used with confidence.

We are now ready to connect up the meter, and with apparatus properly adjusted as shown, we may proceed to determine its accuracy, capacity, and limitations.

In starting a test, water should be turned on and allowed to run long enough to produce normal conditions. Care should be taken that all air is expelled from meters, piezometers, connecting hose, pipes, etc., to avoid vibrations in the mercury columns. If vibrations to any extent continue, they may be partially checked by throttling the controlling valves to the gages, being careful not to entirely shut them off. With everything running in good shape, at the instant the index hand of the meter points to an even number, time should be taken with a good stop watch, and readings of both open mercury gage and of " U " gage should begin. These should be read every minute if columns are fairly steady, otherwise readings every half minute or, in extreme cases of variation, even oftener may be required. There observations should be continued until an even number of cubic feet has been registered by the meter, when, as the index hand points to its proper mark, watch should be stopped, time read, gage readings averaged, and all recorded, completing that test. The length of each run should be sufficient to as nearly as possiple eliminate errors of observation either of time or of index hand of meter, and probably should never be less than three minutes. A run of a definite number of minutes

rather than of a definite number of cubic feet might be made, but it is much easier to start and stop a watch instantly than at a given moment to accurately read a fast-moving index hand. Tests should be repeated under the same conditions as nearly as possible, and so continued until the observer in charge is satisfied with the correctness of the results. Experience will shortly enable one to so handle a stop watch as not to vary more than one fifth of a second in an observation and to read a slightly vibrating mercury column within one tenth of a pound, although at times observations may appear so erratic as to make it advisable to discard them entirely. A good observer, however, will seldom allow this to occur. In general, little or no trouble should be experienced by any member of this Association in getting correct results after suitable practice. This is a class of experiments where as much depends upon the personal factor as upon the apparatus employed.

All tests for the purpose of determining the registration of meters upon small flows were made by discharging into a tank upon a pair of scales, the tank holding about 15 cubic feet of water. The flange connecting the nozzles to the outer piezometer ring was unbolted, and another flange, tapped for 2-inch pipe, bolted on. This 2-inch was further reduced to ¾-inch pipe, and this size was carried over the tank and water discharged into it through a multiple discharge cock, all as shown on Fig. 1, and under substantially the same conditions as are used by us all when testing smaller meters, the weight of the water being used in comparison with the registration of the meter. The only departure from ordinary practice, perhaps, was in taking the time required to discharge specified quantities of water, so that results could be stated in gallons per minute, as being more expressive than otherwise.

RESULTS OF TESTS.

The retardation or loss of pressure in the nine 6-inch meters tested under the direction of the writer is graphically shown on Fig. 2, while the same results are given in Table No. 1 in another form. These are the losses due to the meter alone, experiments having been made to determine the loss of pressure between the piezometer rings, and deductions from the total losses made accordingly.

In Table No. 2 is shown the sensitiveness of these meters in the registration of small flows, that is, those experiments made by means of the weighing tank; while Table No. 3 gives the accuracy on large flows as determined by the nozzle discharges, using the coefficients of discharge previously given.

Table No. 4 shows the approximate number of feet of ordinary straight cast-iron pipe that would cause the same retardation or loss of head under a flow of 500 gallons per minute, or with a velocity equivalent to 5.67 feet per second.

These tables need very little explanation. On Fig. 2 the positions of the experimental points are shown by dots. These so nearly correspond to parabolic curves that, without making the claim that the retardation of any meter follows exactly this law, these curves have all been drawn as parabolas. Further experiments along these lines will be necessary if it is desired to absolutely demonstrate this as a law, but it is believed that for all practical purposes a parabolic curve represents the retardation of a meter, so that given one accurate determination of a point in such curve, it is possible to construct a curve or table of retardation to any extent desired. Following this principle, Table No. 1 has been calculated. The actual observations for retardation alone did not exceed thirty-three pounds loss of pressure, the limit of the "U" gage used, and all retardations in excess of this amount are calculated. In no case, however, has the limit of retardation been carried beyond the actual discharge of the meter in gallons per minute. On Fig. 2 the full line indicates the extent of actual observations of retardation, while the dotted line in extension thereof indicates the calculated retardation at the maximum flow obtained in these experiments.

In comparing results shown in Table No. 2 — "Sensitiveness of Six-Inch Meters in the Registration of Small Flows" — it should be borne in mind that all the meters except the Crown, Empire, and Gem had as their smallest dial one requiring a discharge of 100 cubic feet to allow the index hand to make one revolution. Those dials were, as is usual, divided into ten parts; and while care undoubtedly was taken to make these subdivisions substantially equal, as in no case was the spindle to which the index hand was attached accurately centered within the dial, and as 10 cubic feet was all that could easily be weighed in the weighing

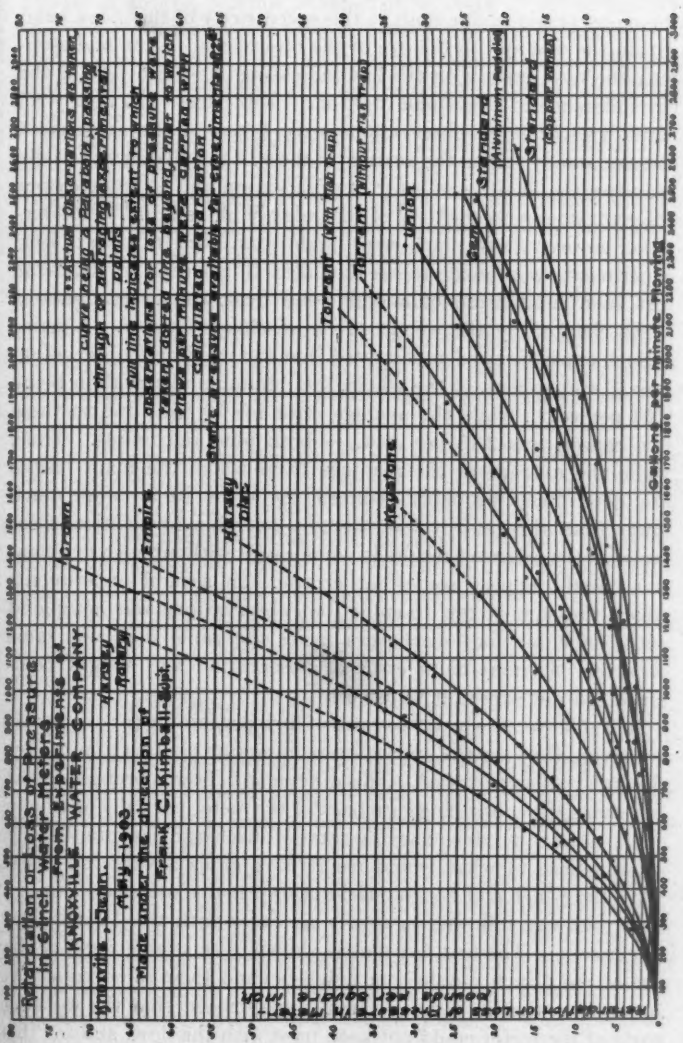

Reduction in Loss of Pressure in 6-inch Water Meters
from Experiments at
KNOXVILLE WATER COMPANY
Knoxville, Tenn.
April, 1903
made under the direction of
Frank C. Kimball, C.E.
Memphis
Gallons per minute, Memphis
Gallons per minute, Knoxville
Gallons per minute, Kansas City
Gallons per minute, Florida
Gallons per minute, Tennessee
Gallons per minute, Kentucky
Gallons per minute, Alabama
Gallons per minute, Georgia
Gallons per minute, Virginia
Gallons per minute, Maryland
Gallons per minute, Pennsylvania
Gallons per minute, New York
Gallons per minute, Massachusetts
Gallons per minute, Connecticut
Gallons per minute, Rhode Island
Gallons per minute, Vermont
Gallons per minute, New Hampshire
Gallons per minute, Maine
Gallons per minute, Canada
Gallons per minute, Mexico
Gallons per minute, Cuba
Gallons per minute, Porto Rico
Gallons per minute, Hawaii
Gallons per minute, Philippines
Gallons per minute, Japan
Gallons per minute, China
Gallons per minute, India
Gallons per minute, Africa
Gallons per minute, Australia
Gallons per minute, New Zealand
Gallons per minute, Tasmania
Gallons per minute, Fiji
Gallons per minute, Samoa
Gallons per minute, Guam
Gallons per minute, Hawaii
Gallons per minute, Philippines
Gallons per minute, Japan
Gallons per minute, China
Gallons per minute, India
Gallons per minute, Africa
Gallons per minute, Australia
Gallons per minute, New Zealand
Gallons per minute, Tasmania
Gallons per minute, Fiji
Gallons per minute, Samoa
Gallons per minute, Guam

FIG. 2.

tank used, at each experiment, there is a possible slight error in these observations, due both to this eccentricity of the index hand within the dial and to the eye of the observer in noting and stopping the flow exactly on the line indicating one-tenth part of the circumference of this small dial, or 10 cubic feet. In nearly all cases, two or more observations were taken of the same sized stream, and by taking the average of these, it resulted in materially reducing the liability of error of observation and to some extent the error due to eccentricity of the index hand and dial. To determine, however, how much error might exist, due to these causes, experiments were made to see how near 10 per cent. of 100 cubic feet each subdivision of a dial could read, the determinations being checked by the weight of the discharged water. A series of such experiments demonstrated that the maximum observation was 10.46 per cent. of the whole, the minimum observation being 9.64 per cent., while the average error for 10 feet, due to these two causes, was 2.15 per cent., — both plus and minus. Thus, while the average of the readings from which the main results are determined probably reduced the error to a point much lower than this, still it was thought desirable to mention these facts, as the recorded results in some cases, without such explanation, might appear somewhat erratic. In several experiments where the sum of ten 10-cubic foot observations was compared with 100-cubic foot discharges using the same dial and same observer, the maximum error of observation and weight combined did not exceed 0.32 per cent.

In Table No. 3, where two rates of flow per minute for one nozzle are given, they are the approximate minimum and maximum flow through that sized orifice. This difference in flow is brought about by having the controlling gate back of the meter partially or wholly open, so as to produce varying rates of discharge per minute, and intermediate to what would result were gates always full open. With the ½-inch and 1-inch nozzles, this practice was seldom necessary, but was followed in nearly all cases with the 1½-inch and larger sizes. The first five meters shown in this table were, in the use of the 4-inch nozzle, run much beyond their rated capacity, so much so that in some of them it is apparent that the working parts of the meter could not keep pace with the flow, and for this reason the average per cent. of meter discharge to nozzle discharge,

shown in the last column, should not be taken as the actual performance of these meters without taking this fact into consideration. To construct this table the average of all experiments made with the same nozzle, meter, and approximate rate of flow was taken.

Table No. 4 is calculated from the observed losses of head, with the aid of " Diagrams and Hydraulic Data Relating to the Flow of Water in Cast-Iron Pipes," by Leonard Metcalf, Assoc. M. Am. Soc. C. E., Boston, Mass., as published in the *Engineering Record*, June 20, 1903, and needs no further explanation.

EFFECT OF FISH TRAPS ON METERS.

Of the meters tested the Hersey Rotary, Hersey Disc, Union, and Standard had no fish trap or strainer as a part of their meter. Tests were made upon the others to determine what the effect of these strainers was.

The effect of the Torrent meter is shown on Fig. 2 and in Table No. 1 both with and without strainer. The area of the openings in this strainer is equivalent to 1.25 times that of a 6-inch pipe.

The Crown meter is shown with strainer. Without, the retardation averages about 10 per cent. less, the area of openings in this strainer being about 2.25 times that of a 6-inch pipe.

The Empire meter shows no difference whether with or without strainer, the area of openings being about 3 times that of a 6-inch pipe.

The Keystone meter is shown with a strainer which has openings equivalent to 1.9 the area of a 6-inch pipe. The retardation without strainer averages about 10 per cent. less than with.

The Gem meter shows no appreciable difference, either with or without strainer, the area of openings in which is about 3 times that of a 6-inch pipe.

These can be considered as *minimum* obstructions or retardation due to the strainers or fish traps furnished with these several meters. The water used in these experiments was all filtered and came directly from the clear water reservoir of the plant, through a pipe from which all mud and sediment had been blown out. In ordinary practice, where little or no water is usually drawn through these meters, and especially with water containing sediment in the shape of mud, sticks, leaves, etc., when a large draft is

made through them, as in case of fire, the loss by stopping up more or less of the small holes in the strainer will be much more. For this reason the writer believes that where strainers are necessary, and perhaps in all cases, a special fish trap should be used, with an area of openings equivalent to about five or six times that of a 6-inch pipe. This can be bolted directly to the meter, though independent of it, and should be provided with a removable cover or hand plate to insure ease in inspecting and cleaning. Where meters are attached to a fire protection system, the strainer should be inspected as regularly and as often as are the other portions of the system. From tests made, an area of openings three times that of the area of the pipe seems adequate to eliminate friction loss when clean; and with area of twice this amount, something over half can become clogged or covered without affecting the flow of water, and with ordinary inspection and a water supply suitable for domestic uses, this should insure perfect safety in the use of such fish trap.

SPECIAL TESTS AND CONDITIONS.

A strong point usually made by insurance inspectors against the use of rotary, piston, or disc meters upon fire protection lines is their liability to clog, stop, and break by foreign matter carried into them from pipe lines and lodging in their moving parts and wedging. While this can hardly result if use is made of large-area strainers, some experiments were made along these lines.

The Crown meter was completely blocked by the insertion of two wooden wedges between piston and casing. In this condition, the following results were obtained:

Size Nozzle Used, Inches.	*Discharge, Gallons per Minute.*	*Loss of Pressure, Pounds.*
1	204	40
1½	338	55
2	479	62
2½	575	69

While the test with 2½-inch nozzle was under way, seven of the eight screws fastening the interior cover plate to the casing gave way, allowing this plate to lift. The meter in this shape, still blocked, however, so that the piston could not move, discharged with 2½-inch nozzle at the rate of 1 329 gallons per minute, with loss of pressure of 18.3 pounds, and with 4-inch nozzle, 2 128 gallons, with loss of pressure of 24 pounds. This would seem to show

FIG. 1. — GENERAL VIEW OF APPARATUS USED.

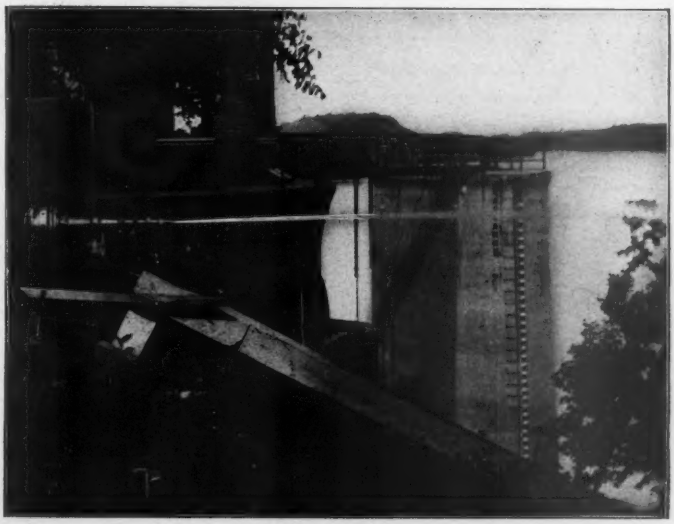


FIG. 2. — DISCHARGE THROUGH ½-INCH NOZZLE. 67 GALLONS PER MINUTE (EMPIRE METER).

that a sudden stopping of this meter by piston becoming blocked would result in tearing away the cover plate, allowing water to flow with much more freedom than before. After this test it was found that the cover plate had been slightly sprung. This was straightened by a hammer, on the ground, bolted back into place, and the meter tested again on small flows. Results fully as accurate as before it broke were obtained, showing that no injury to the meter itself to any extent had resulted.

The Gem meter also had its working parts completely blocked, and in this condition the following results were obtained:

Size Nozzle Used, Inches.	*Discharge, Gallons per Minute.*	*Loss of Pressure, Pounds.*	*Increased Loss over Meter running Free, Pounds.*
2	1003	4.5	0.5
2½	1411	9.3	1.3
4	2457	26.8	2.9

This shows a difference in loss of pressure as between meter running free and with moving parts blocked, of between 10 per cent. and 15 per cent. only.

The effect upon the flow through a disc meter when disc is broken and the pieces wedged by the force of the water into the outlet was shown by the Hersey Disc. This meter was tested to a finish, so far as the disc was concerned. While discharging at a rate of 1 455 gallons per minute (guaranteed capacity being 900 gallons, an excess of upwards of 60 per cent. in flow) the disc broke into several pieces. Without in any way changing the conditions of supply, a discharge was obtained, as shown by the nozzle, through this meter of about 1 218 gallons per minute, and with substantially the same loss of head as before it broke. This would indicate a discharge, under the most adverse conditions possible in a meter of this character, of about 86 per cent. of the free flow of such meter, certainly not enough of a difference to warrant discarding meters of this type on account of liability of breakage at such high velocities. The replacement of the disc with a new one was all that was required to again place the meter in proper working order.

The Keystone disc meter, which also has a guaranteed capacity of only 900 gallons per minute, was tested to a discharge of 1 518 gallons, being an excessive discharge of about 69 per cent., at which rate this disc also broke. While no tests were made of the performance of this meter under these conditions, from the

writer's knowledge of it and a thorough examination of the meter both before and after breaking, he is justified in stating that similar results would have been obtained as with the other disc meter. As, therefore, these disc meters have proved themselves capable of delivering considerably more than 50 per cent. in excess of their nominal capacity safely, and, when circumstances call for an even greater delivery, to the point of breaking without very materially reducing the available flow, no hesitancy should be shown in using this type on this account alone.

All other meters were tested to the full extent that the available pressure and apparatus would permit, regardless of any limitations as to capacity placed upon them by the manufacturers, and the tables show the extent to which these tests were carried. In only one meter, beside the two disc meters mentioned, was there any breakage due to the construction of the piston, disc, or vanes, and this was in the Standard meter, where with the curved copper vanes on the shaft, under the maximum discharge of 2 648 gallons per minute, three of the vanes were stripped off. To this point everything held, and as this was in excess of any probable working discharge through a meter of this description, unless placed upon a pipe line larger in size than the meter, it should not operate against it. Since these tests the writer understands that these vanes have been further reinforced so as to withstand these excessive discharges.

The views shown on Plates II and III are sufficiently well explained by their titles, and are of interest simply in giving an eye impression of both the apparatus used and streams discharged.

EFFECT OF METERS UPON FIRE STREAMS.

This question is so broad and has been discussed heretofore in so many of its phases that the writer does not deem it advisable to include it in the scope of this paper.

It is his hope, however, that herein may be found information that will be useful in settling questions always arising as to the performance of large-sized meters, and possibly assist in bringing about improvements therein which will more thoroughly draw together the present opposing ideas of water departments and insurance underwriters. All the manufacturers whose meters were represented in these tests have some time since received

FIG. 1. — DISCHARGE THROUGH CROWN METER AFTER COVER PLATE HAD GIVEN WAY, AND 4-INCH NOZZLE, — 2 128 GALLONS PER MINUTE.

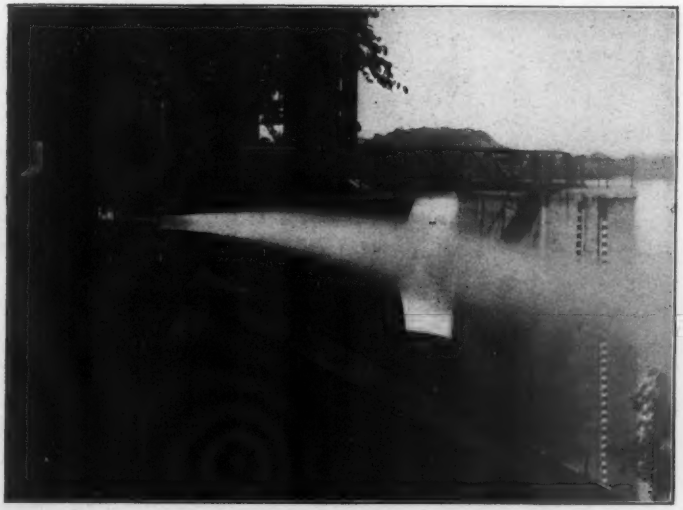


FIG. 2. — DISCHARGE THROUGH HERSEY DISC METER AFTER DISC WAS BROKEN, AND 4-INCH NOZZLE, — 1 218 GALLONS PER MINUTE.

copies of the preliminary results, and numerous suggestions and remarks thereon have been made to the writer. Generally it has been thought advisable not to specifically deal with these, but to leave them for such discussion as the subject may invoke. It has also been the writer's pleasure to have personal conferences with several of them since these results have been known. At one of these informal talks, a gentleman prominently connected with one of the leading meter companies informed the writer that they were already working upon a meter which for fineness of registration would be equal to the best of those shown in these results, while the loss of pressure or retardation would not be in excess of that of the best types of current meters, also herein shown. He was not, however, in position to state with much more definiteness at that time just what the nature of this meter would be, except that it would not be a current meter, as certain details had then to be worked out before further exploiting it. This shows that the manufacturers are alive to the requirements of the situation, and a thorough discussion at this time, both of results obtained and those desired, would be of decided advantage to all concerned.

TABLE No. 1.

RETARDATION, OR LOSS OF PRESSURE, IN SIX-INCH WATER METERS. POUNDS PER SQUARE INCH.

Gallons per Minute Flowing through Meter.	Hersey Rotary.	Crown.	Empire.	Hersey Disc.	Keystone.	Torrent with Fish Trap.	Torrent without Fish Trap.	Union.	Gem.	Standard, Aluminum Paddles.	Standard, Copper Vanes.	Gallons per Minute Flowing through Meter.
50	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50
100	0.5	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	100
150	1.1	0.9	0.7	0.5	0.3	0.2	0.2	0.1	0.1	0.1	0.1	150
200	1.9	1.5	1.3	1.0	0.5	0.3	0.3	0.2	0.2	0.1	0.1	200
250	3.0	2.4	2.1	1.5	0.8	0.5	0.5	0.3	0.3	0.2	0.2	250
300	4.3	3.4	3.0	2.2	1.2	0.8	0.7	0.5	0.4	0.3	0.2	300
350	5.8	4.7	4.0	3.0	1.6	1.1	0.9	0.7	0.5	0.4	0.3	350
400	7.6	6.1	5.3	4.0	2.1	1.4	1.2	0.9	0.6	0.6	0.4	400
450	9.7	7.7	6.7	5.0	2.7	1.7	1.5	1.1	0.8	0.8	0.5	450
500	11.9	9.6	8.2	6.2	3.3	2.2	1.8	1.4	1.0	0.9	0.7	500
550	14.4	11.6	10.0	7.5	4.0	2.6	2.2	1.7	1.2	1.1	0.8	550
600	17.2	13.8	11.9	8.9	4.8	3.1	2.7	2.0	1.4	1.3	1.0	600
650	20.2	16.2	13.9	10.5	5.6	3.7	3.1	2.3	1.7	1.6	1.1	650
700	23.4	18.7	16.2	12.1	6.6	4.2	3.6	2.7	2.0	1.8	1.3	700
750	26.9	21.5	18.6	13.9	7.5	4.9	4.2	3.1	2.2	2.1	1.5	750
800	30.6	24.5	21.1	15.8	8.6	5.5	4.7	3.6	2.5	2.4	1.7	800
850	34.5	27.6	23.9	17.9	9.7	6.3	5.4	4.0	2.9	2.7	1.9	850
900	38.7	31.0	26.7	20.1	10.8	7.0	6.0	4.5	3.2	3.0	2.2	900
950	43.1	34.5	29.8	22.3	12.1	7.8	6.7	5.0	3.6	3.4	2.4	950
1 000	47.8	38.2	33.2	24.8	13.4	8.7	7.4	5.6	4.0	3.7	2.7	1 000

1 050	52.7	42.2	36.4	27.3	14.7	9.5	8.2	6.1	4.4	4.1	3.0	1 050
1 100	57.8	46.3	39.9	30.0	16.2	10.5	9.0	6.7	4.8	4.5	3.2	1 100
1 150	63.2	50.6	43.7	32.8	17.7	11.5	9.8	7.4	5.3	4.9	3.6	1 150
1 200	68.9	55.1	47.5	35.7	19.3	12.5	10.7	8.0	5.7	5.4	3.9	1 200
1 250		59.8	51.6	38.7	20.9	13.5	11.6	8.7	6.2	5.8	4.2	1 250
1 300		64.7	55.8	41.9	22.6	14.6	12.5	9.4	6.7	6.3	4.6	1 300
1 350		69.7	60.2	45.1	24.4	15.8	13.5	10.1	7.3	6.8	4.9	1 350
1 400		75.0	64.7	48.5	26.2	17.0	14.5	10.9	7.8	7.3	5.3	1 400
1 450				52.1	28.1	18.2	15.6	11.7	8.4	7.9	5.7	1 450
1 500					30.1	19.5	16.7	12.5	9.0	8.4	6.1	1 500
1 550					32.1	20.8	17.8	13.4	9.6	9.0	6.5	1 550
1 600						22.2	19.0	14.3	10.2	9.6	6.9	1 600
1 650						23.6	20.2	15.2	10.8	10.2	7.3	1 650
1 700						25.0	21.4	16.1	11.5	10.8	7.8	1 700
1 750						26.5	22.7	17.1	12.2	11.5	8.2	1 750
1 800						28.1	24.0	18.0	12.9	12.1	8.7	1 800
1 850						29.6	25.4	19.1	13.6	12 8	9.2	1 850
1 900						31.3	26.8	20.1	14.4	13.5	9.7	1 900
1 950						32.9	28.2	21.2	15.1	14.2	10.2	1 950
2 000						34.6	29.6	22.3	15.9	15.0	10.8	2 000
2 050						36.4	31.1	23.4	16.7	15.7	11.3	2 050
2 100						38.2	32.7	24.6	17.6	16.5	11.9	2 100
2 150						40.0	34.3	25.7	18.4	17.3	12.5	2 150
2 200							35.9	27.0	19.3	18.1	13.0	2 200
2 250							37.5	28.2	20.2	19.0	13.6	2 250
2 300								29.5	21.1	19.8	14.3	2 300
2 350								30.7	22.0	20.7	14.9	2 350
2 400									22.9	21.6	15.5	2 400
2 450									23.9	22.5	16.2	2 450
2 500									24.9	23.4	16.8	2 500

TABLE No. 2.

SENSITIVENESS OF SIX-INCH WATER METERS IN THE REGISTRATION OF SMALL FLOWS.

METER.	¼-INCH OPENING.				⅜-INCH OPENING.				½-INCH OPENING.				⅝-INCH OPENING.				1/16-INCH OPENING.			
	Gallons per minute.		Unrecorded Flow.		Gallons per Minute.		Unrecorded Flow		Gallons per Minute.		Unrecorded Flow.		Gallons per Minute.		Unrecorded Flow.		Gallons per Minute.		Unrecorded Flow.	
	By Weight.	By Meter.	Gallons.	Per Cent.	By Weight.	By Meter.	Gallons.	Per Cent.	By Weight.	By Meter.	Gallons.	Per Cent.	By Weight.	By Meter.	Gallons.	Per Cent.	By Weight.	By Meter.	Gallons.	Per Cent.
Crown	39.35	38.70	0.65	1.3	25.12	24.86	0.26	1.0	11.68	11.34	0.34	2.9	3.01	2.74	0.27	9.0	0.76	0.38	0.38	50.0
Hersey Disc	38.21	38.98	+0.77	+ 2.0	24.73	24.13	0.60	2.4	11.61	11.33	0.28	2.5	2.99	2.55	0.44	14.6	0.75	0.34	0.41	54.7
Empire	40.09	39.03	1.06	2.7	24.34	23.62	0.72	3.0	11.62	11.46	0.16	1.4	3.11	2.79	0.32	10.4	0.75	0.32	0.43	57.7
Keystone	38.77	34.64	4.13	10.7	24.86	22.88	1.98	8.0	11.66	10.64	1.08	9.3	3.12	0.52	2.60	83.4				
Union	38.38	37.56	0.82	2.1	25.05	22.78	2.27	9.0	11.66	8.36	3.30	28.3								
Gem	38.28	37.56	0.73	1.9	22.93	20.49	2.44	10.6	11.42	5.69	5.73	50.2								
Torrent	38.59	36.93	1.65	4.3	24.97	23.09	1.88	7.6	11.58	6.03	5.55	47.9								
Hersey Rotary	38.08	36.52	1.56	4.1	25.14	20.43	4.71	18.7												
Standard	38.18	24.26	13.92	36.5																

TABLE No. 3.

TABLE No. 3.

ACCURACY OF SIX-INCH METERS ON LARGE FLOWS, AS DETERMINED BY NOZZLE DISCHARGES; SHOWING MINIMUM AND MAXIMUM RATES OF FLOW FOR EACH NOZZLE, AND PER CENT. OF METER DISCHARGE TO NOZZLE DISCHARGE.

METER.	½-INCH NOZZLE.		1-INCH NOZZLE.		1½-INCH NOZZLE.		2-INCH NOZZLE.		2½-INCH NOZZLE.		4-INCH NOZZLE.		AVERAGE PER CENT. ALL NOZZLES, GIVING EACH EQUAL WEIGHT.
	Gallons per Minute.	Per Cent.	Gallons per Minute.	Per Cent.	Gallons per Minute.	Per Cent.	Gallons per Minute.	Per Cent.	Gallons per Minute.	Per Cent.	Gallons per Minute.	Per Cent.	
Hersey Rotary	67	98.6	278	100.7	408 to 537	99.5	580 to 807	99.7	805 to 965	99.9	1 195	100.1	99.7
Crown	67	99.2	215 to 280	99.6	434 to 550	97.3	606 to 847	95.9	868 to 944	97.4	1 409	87.3	96.1
Empire	67	99.5	282	99.9	440 to 554	98.3	655 to 866	99.4	950 to 1 092	100.9	1 350 to 1 420	97.2	99.2
Hersey Disc	67	100.7	283	99.5	412 to 561	99.3	626 to 894	100.7	945 to 1 145	102.8	1 217 to 1 455	99.7	100.4
Keystone	67	100.0	284	101.6	574	100.0	787 to 953	101.3	1 065 to 1 301	102.8	1 518		101.1
Torrent	67	101.8	285	102.4	446 to 582	100.3	789 to 982	103.4	1 063 to 1 379	104.5	1 474 to 2 220	99.6	102.0
Union	67	98.6	285	100.9	583	99.3	850 to 996	100.2	1 193 to 1 378	101.2	1 730 to 2 341	96.8	99.5
Gem	67	99.7	286	98.6	587	97.7	848 to 1 004	99.2	1 198 to 1 430	100.4	1 753 to 2 506	97.9	98.9

TABLE No. 4.

APPROXIMATE NUMBER OF FEET OF ORDINARY STRAIGHT CLEAN CAST-IRON PIPE THAT WOULD CAUSE THE SAME RETARDATION OR LOSS OF PRESSURE AS THE METERS, UNDER A FLOW OF 500 GALLONS PER MINUTE, BEING A VELOCITY OF 5.67 FEET PER SECOND.

METER.	FEET OF PIPE.
Hersey Rotary	1 340
Crown	1 070
Empire	920
Hersey Disc	690
Keystone	370
Torrent, with Fish Trap	240
Torrent, without Fish Trap	210
Union	160
Gem	110
Standard, Aluminum Paddles	100
Standard, Copper Vanes	80

CONCLUSION.

While these tests were made under the immediate direction of the writer, at no time during the eighteen days they were in progress was he without the advice and assistance of other gentlemen well qualified to coöperate in work of this description. The meter manufacturers were represented by Mr. D. A. Munroe, Superintendent of the Pittsburg Meter Company, and Mr. J. A. Tilden, General Manager of the Hersey Manufacturing Company. Mr. A. W. Hardy and Mr. Sanderson, Inspectors of Automatic Sprinkler Risks of various stock insurance companies operating in the central and southern sections of the country, and Mr. C. H. Smith, Inspector for the Factory Mutual Fire Insurance Companies of Boston, represented the underwriters' interests; while Mr. F. H. Crandall, of Burlington, Vt., who needs no introduction to you, was sufficiently interested in these tests to come to Tennessee and spend ten days with us. It can therefore be said that in no sense were these experiments *ex parte*. In addition to the personal presence of these gentlemen we were largely assisted by the advice, both personal and by letter, of Mr. E. V. French, of the Factory Mutuals, who has had large experience in this class of experimental work, and also by the loan of apparatus both by the

Factory Mutual Companies and by the Hersey Manufacturing Company. To all these parties, to the meter companies who so kindly furnished meters for these tests, to Messrs. John A. Durham and Wellington Donaldson of the local force of the Knoxville Water Company, who materially assisted in this work, and particularly to Gen. Elbert Wheeler, Treasurer of the Knoxville Water Company, both for permission to use results obtained and valuable assistance in compiling the same, the writer desires to express his full appreciation.

DISCUSSION.

MR. F. H. CRANDALL.* *Mr. President and Gentlemen of the Association,* — It was my privilege to be present during a large part of the work which was done by Mr. Kimball at Knoxville, and I regret as much as any of you that Mr. Kimball was not able to be here to read his paper and to talk about it himself. The Knoxville Water Company, being a private company, is perhaps a little more interested, or appreciates the suggestion in regard to furnishing water for nothing for private fire pipes more keenly than public corporations do; and they have been to a very considerable expense in preparing for and doing the work of ascertaining what the efficiency and what the effect of the different classes of meters at present on the market would be upon the fire service. The general idea seemed to be that some accident would happen to almost any meter when it was called upon to deliver a large quantity of water, and that the result would be disastrous. I think it has been plainly shown that that opinion is erroneous. It has been shown at Knoxville, outside of these tests, that a by-pass can be opened if necessity calls for its being opened. The water company employs a man whose duty it is to be present at every fire. There were several fires while I was there, and about the first man I saw at the fire -- and I got there among the first — was the man from the water works; and if there had been occasion for the opening of a by-pass I am perfectly satisfied he would have got it open.

The blocking of the different meters that were blocked was done in such an effective manner as never would have happened accidentally. A Crown meter, for instance, never could have been stopped up in the way the Crown meter was stopped up in the

* Superintendent of Water Works, Burlington, Vt.

test. There were two pieces of 2 by 4 joist placed inside the meter on opposite sides of the float, so that it was absolutely prevented from moving. When the difference in pressure became sufficient to overcome the strength of the screws in the division plate, the division plate gave way, and the discharge of the meter increased 50 per cent., as you see by the tables. The disc meter, which was injured also, increased its discharge after injury.

The insurance people, particularly the Factory Mutual people, joined with Mr. Kimball in the attempt to ascertain the facts in regard to these meters, loaned him material, and had a representative on the ground for a considerable length of time, and appeared in every way to be interested in a satisfactory solution of the question. The insurance people naturally want to make assurance doubly sure and take a bond of fate. The water-works people want to have absolutely good assurance that they will not be defrauded by the use of services over which there is no control. The devices or meters which were tested, as you can see from the published results, do not record the very finest flows. Those that do probably will not record them for any great length of time after they have been worn in service, and those that are the most accurate in the measurement of water afford the greatest obstruction to the flow. There are at present two devices which I know of, and I believe that there are more in process of construction, by which it is hoped to overcome, to a considerably greater degree, the objections to meters at present on the market.

Mr. J. A. Tilden.* Mr. President, it was my pleasure to be present at Knoxville during the last few days of the meter tests which form the subject of the paper which has just been read. I think that the water meter companies, as well as our water-works friends, are very much indebted to the Knoxville Water Company, to Mr. Wheeler, and to Mr. Kimball in particular, for the efficient manner and for the careful manner in which these tests were carried out. In a sense one might say that these tests were competitive or comparative, and from that point of view they are of special interest to the meter manufacturers. We had opportunities at Knoxville for the use of a very large amount of water; that is, we had a 6-inch pipe leading directly from a 14-inch main at 80 pounds pressure, or thereabouts, and dis-

* Hersey Mfg. Co., South Boston, Mass.

charging directly into the river without any elbows or curves, giving us in that way a very much larger amount of water and at a greater head than any of us have in our factories; and we had, therefore, an opportunity for comparison which I think has never before been presented.

I think all meter companies should welcome comparative tests of this kind. We all want to know what our meters will do, and we want to know what they will do in comparison with those of other manufacturers; then it remains for our water-works friends to decide. I think we all, both manufacturers and water-works people, are very glad to have these tables showing these comparisons, and we appreciate them from the fact that it takes time and it takes money to go through a series of tests of this kind. The Knoxville Water Company put in a good deal of time and not a little expense; the meter companies, as Mr. Kimball has said, loaned the meters and the apparatus.

I am very glad to note that as the result of the tests, or as one of the outcomes of the test, one of our New England water works, namely, that at Burlington, Vt., of which Mr. Crandall is superintendent, is preparing to test on a scale as elaborate as that at Knoxville. Many of you have apparatus for testing meters which is more or less elaborate, but ordinarily it is of somewhat limited capacity, that is, of a capacity only suitable for testing small meters. There are very few places in the country where meters can be tested at the rate at which they were tested in Knoxville. You will observe they got discharges there as high as 3 000 gallons a minute, and Mr. Crandall will have an opportunity to put through the same amount. The outcome of a movement in this direction, that is, toward the testing of large meters on an extensive scale, will be to put in the hands of water-works people valuable information, and it will also be a very good lesson for the meter companies. The result will be the improvement of meters for some of the particular services for which these large meters are wanted, that is, for large manufacturing establishments for fire protection, for the supplies of smaller cities and towns by larger ones, for hydraulic elevators, and the like.

The purpose of my remarks is simply to show that this is a step in the right direction, valuable alike to the water departments

and to the manufacturers of water meters. I thank you very much for the opportunity to say these few words.

MR. FRANK C. KIMBALL (*by letter, November* 27, 1903). Since the preparation of my paper we have had opportunity to observe the practical effect of meters upon fire streams here at Knoxville. A woodworking establishment, situated about two miles outside of town, has an equipment of automatic sprinklers with two fire hydrants connected with the supplying pipes in the yard of the mill. The installation is fed through a 6-inch pipe, metered by a 6-inch Crown meter in bypass, with indicator post gate in main line, in exact accordance with the " sketch of standard metered fire connection," as shown on p. 219 of Vol. 16 of the JOURNAL of this Association. This connection at the present time is also at the end of a line of pipe consisting of about 1 300 feet of 6-inch pipe and 300 feet of 8-inch pipe connecting with a 10-inch main, all of which was laid for this particular factory, so that the conditions as to friction loss under heavy discharges are not as good as might be desired or as they may be later when this 6-inch line is completed by a circuit. Beyond this meter the pipe is tapped, and boiler and other supplies for the mill are taken, so that this 6-inch meter controls all uses for this purpose. In adjoining premises is a mattress factory, and among the buildings comprising the same was a warehouse for storing excelsior. These premises had no fire protection, the excelsior storehouse being between 200 and 300 feet from the nearest hydrant in the premises supplied. A fire started one afternoon recently in this excelsior warehouse, and was well under way before being discovered; this warehouse was of wooden construction. Two 2½-inch fire streams were taken off the nearer of the two hydrants by the employees of these two establishments, and while, from the nature of the building and its contents, very little of these were saved, all the surrounding buildings, as well as piles of lumber stacked in the yards for drying purposes, were kept from burning or even scorching to any appreciable extent. Being outside the corporate limits of the city, no alarm was sent in, but the water company was notified; and as quickly as possible, as usual, one of its employees was on the ground, when it was found that the sealed gate had not been opened. Investigating the reason, it was found that the engineer of the protected establish-

ment, who had charge of the mill's fire brigade, while having this bypass gate thoroughly in mind, even to the extent of going to it and seeing that it was ready to operate with wrench, etc., concluded that he would like to see how these streams would work through a meter, and therefore did not open the gate; and his statement as to the effect of these streams was, that after seeing the way they worked, he did not dare to open the gate, as his men would not have been able to control the streams if the pressure had been any greater. As it was, the force of the stream was sufficient, after an entrance into the sides of the building by axes had been made, to thoroughly tear off the boarding and scatter the contents of the warehouse. The pressure at this point is ordinarily about 100 pounds per square inch, and the engineer states that at no time during the fire did his water pressure gage in the engine room show less than, as he put it, from 75 to 80 pounds, which, taking into consideration the long length of pipe, as well as the obstruction offered by the bypass and meter, cannot but be regarded as an excellent result.

I think Mr. Crandall's idea that meters in the 6-inch size will not record small or fine flows for any great length of time after they have been in service is not wholly borne out by facts, except perhaps as drawn from his experience with smaller meters. While undoubtedly water of a gritty nature, or having foreign matter in suspension, will have an influence upon the wearing parts of meters, large as well as small, our experience here with filtered water shows very little trouble along these lines. Since the fire above mentioned, that particular meter has been tested for accuracy, and its unrecorded flow was less than half a gallon per minute on all streams except with 1-16 inch opening, where it was about three-quarters of a gallon per minute, showing that the use it had been put to had not materially affected its sensitiveness. This meter was set in November, 1901, and to date has registered about 520 000 cubic feet. As an example of how a meter set as this one is can be tested at comparatively small expense, and without removing it from its place, it may be of interest to the Association to know that this was done in six or eight hours' time when the factory was not running, first seeing that all outlets were closed and that the meter did not register or move for some considerable period, thus showing that the piping was

all tight and no unaccounted for water passing through the meter. A ¾-inch meter, which had previously been calibrated, was then attached to a convenient pipe in the boiler room, and various, sized streams, from ¾ inch down, were run through this meter, and the readings of the small meter, after corrections, were compared with the larger meter, and the above results obtained. Between observations some considerable time was allowed to elapse during which the larger meter was carefully observed to see if in the meanwhile any water was passing through it, and the result in all cases being negative, I think we can safely rely upon the results shown. This to me at least shows that for the limited time and quantity used by this meter, including one fairly good fire test, it has lost none of its accuracy. I think if water-works managers, in places where large meters are set, would, from time to time, have them tested in some such comparatively inexpensive way, and at the same time give us the benefit of such experience as they may have in regard to large uses of water through such meters for fire or other purposes, that it would be of very great interest to this Association as showing in practice, as well as in tests, what large-sized meters are capable of doing.

I have been pleased to learn that the Water Department at Burlington, Vt., has taken the initiative in New England in establishing a permanent testing plant for large meters or devices requiring a large supply of water, to properly demonstrate their ability and capacity. I have also followed by correspondence the tests made upon an automatic regulating gate to be used in place of a manually operated gate upon fire services, and believe these are all steps in the right direction toward obtaining and maintaining that degree of protection and inspection to water departments that is so essential to the proper conduct of their business, and cannot but believe that all these experiments and determinations will result in producing and perfecting controlling devices and registering apparatus in the shape of meters or otherwise that will, and very shortly, bring water departments and insurance underwriters upon a common ground, to the mutual advantage of both. I am also glad to note in Mr. Tilden's remarks that meter manufacturers are in line and sympathy with this movement to thoroughly test meters on a large scale, as it

shows their desire, already known to the writer, to give to water departments the best that their experience and ability can produce, and the only result possible from this hearty co-operation of all concerned will be to bring about results in which every one can but have confidence.

THE RECIPROCAL OBLIGATIONS OF THE MANAGEMENT OF A WATER SUPPLY SYSTEM AND THE COMMUNITY.

BY JOHN O. HALL, EX-MAYOR, QUINCY, MASS.

[*Read September 10, 1903.*]

Many students of political economy believe that the problems of the cities are those which most affect the progress of the race; that the forces which are potent in the cities of the land are those which make or mar the nation. Certain it is that all who become in any way familiar with governments of large communities realize that there are many powerful influences at all times in operation in these governments which will work dire disaster to those communities and so to the state and the nation unless they are checked in their activities and as much as possible forced out of immediate operation and driven into the background.

To any one connected with the government of one of the larger or smaller cities of the land who seeks to administer his office on the broad lines of strict business principles and with an eye single to the best interests of the community, there opens a pathway beset with a multitude of problems difficult of solution and hedged about with numerous forces and interests antagonistic to those lines and very active and belligerent in their opposition.

The problems which beset the governments of large communities are becoming at the present time very complex, and the tendency is to decide them, in very many cases, on the policy of a temporary expediency or political advantage, rather than on their merits and for the welfare of the community.

Of the many departments of municipal governments, none contains more perplexing problems than the water department, and in what I shall say on the subject in hand, I shall endeavor to treat these problems on the line of an honest attempt to administer this department for the public welfare, regardless of personal advantage or political policies.

My experience has taught me that the line of economy and the public welfare is the true one for the best results. The axiom

that "honesty is the best policy" most certainly holds true in the administration of public affairs, for however much we may seem to secure by an abandonment of what we acknowledge to be an honest course in any given question, in the end those who abandon such a course are sure to meet disaster, and the community of innocent citizens must pay the added cost.

The policy of nearly every government of a large community at the present day is too much in the line of unwise extravagance, and is a departure from sound business principles and honest effort for the public good.

The rapid growth of American cities and the requirements of modern civilization make the demand for a sufficient and efficient water supply more and more serious with each succeeding year, and the duty of the governments of cities to provide and administer such a supply becomes more and more onerous.

To secure and administer such a supply for only the purely domestic uses is quite simple, but by reason of the rapid growth of population, crowding large numbers into a comparatively small district, the necessity arises for providing a system of sewerage, and this very largely increases the draft on the water supply. Further, by reason of this crowding of people, the added demand exists for a source of supply remote from the dense population, in order, as much as possible, to avoid contamination by impurities which would be detrimental to the public health.

Added to this is the demand for water for the extinguishment of fire. From a comparatively simple acquirement which would allow pure water to flow into the houses of the citizens, we are forced to the consideration of the more extended and complex one of providing an abundant supply with a sufficient pressure to enable the fire department to cope with possible conflagrations. To meet these demands requires the still further and very large expense of pumping and storing at high elevations.

Under the teachings of our present civilization, the obligation rests upon governments to make this supply pure and ample for all purposes, for it is conducive to the welfare of the community, whether we consider that welfare from the point of health, education, or the beauty of surroundings; and it should be furnished wherever desired by the citizens, regardless of the immediate revenue which may be returned in the form of water rates.

We may divide the purposes for which governments of communities are under obligation to those communities to supply water into the following:

1. Domestic uses: *i. e.*, purely for household economy.
2. Sewerage: bath and toilet facilities.
3. Fire extinguishment.

The uses of water may be classed as public and private, and may be divided as follows:

Domestic and Sewerage. — Private: Within the building and upon the grounds of houses, hotels, factories, laundries, and livery stables. Public: Public buildings, fountains, public lavatories, street drinking fountains, street sprinkling, and public baths.

Fire Extinguishment. — Public and private.

Loss. — Leakage: In the system. Waste: By the takers.

The uses of water may further be classed as domestic and financial, and we have:

Domestic. — Private houses and grounds, hotels and apartment houses, street drinking fountains, public buildings, fountains, lavatories, and baths.

Financial. — Factories, laundries, livery stables, street watering. public and private fire extinguishment.

If the supply of water for any given system was unlimited and sure to be in excess of any demand that would be made upon it, we might eliminate the item of loss from our consideration; but unfortunately that is not the case. Water is not free, but, on the contrary, can only be secured at a large cost; and therefore the obligation rests upon every board of management of a water-supply system, every superintendent or water commissioner, to so carefully watch the distribution pipes that the loss of water in the system is reduced to the minimum and that the waste by the takers upon their premises is paid for.

Waste or leakage from the system before the water reaches the consumer must attach to the responsibility of the administration of the water department, and must become a part of the expense and be included in the general tax; waste or leakage on the premises of the consumer is his responsibility and for it he should pay. The private taker should not attempt to place the responsibility of detecting his carelessness or dishonesty upon the government of his city.

The obligation therefore rests to-day upon every community to furnish itself with a supply of water, and upon its government is imposed the duty of administering that obligation; and this implies the proper introduction and distribution of the supply and the just and equitable apportionment of the expense upon the community. This obligation may be discharged by a community establishing its individual plant, or by combining with one or more communities in such establishment, or by taking advantage of a system established by private capital. I shall speak upon this subject primarily from the point of supply under the control of a community, but much that relates to a community supply will apply equally to one under private ownership and control.

In the methods of administration in Massachusetts, and I think in most if not all of the communities represented in the New England Water Works Association, the water department stands as a separate item in the community expense in this regard, that while the community credit is pledged for the establishment of the plant, the revenue for the redemption of that debt and for the interest and maintenance comes alone from the water takers. This I believe to be wrong in principle and to be unfair to the general citizen.

The introduction and distribution of water, like every other department of the public service, is for the general welfare, and therefore the expense attending upon such establishment should be borne by the real and personal property of the community and should appear in the general tax.

Water has ceased to be a convenience or a luxury, but has become an essential department of municipal affairs. Neighbors have crowded in upon the individual, forcing him to abandon his well, and therefore all should share in the expense of the substitution of another supply. For this reason the contention at law that a difference exists between the water department and the other departments of municipal administration, and that the water service exists as a business enterprise and is outside the pale of the rights and privileges appertaining to the other departments which are claimed to exist for the safety and convenience of the public, I believe to be wrong.

The expense incurred in the establishment of the water sys-

tem — which should include the cost of preliminary surveys and incidental expenses, cost of construction of main aqueduct, dam, reservoir, standpipe, and pumping station, the lines of distribution through the community and hydrant connections — should all be borne by the community and appear in the general tax each year in the annual provision for the maturing debt and interest.

The maintenance of the system, which includes the cost of water furnished and the cost of connections with real estate, should be borne by the individual takers.

It is admitted that there is nothing unfair in this apportionment, for the entire holdings of the community are benefited by the existence of an efficient water system and therefore should of right bear their proportion of the expense. The force of this claim is recognized by many officials, as is evidenced by the practice of charging an additional rate based on the valuation of the property.

As it is at present, the water taker is taxed for municipal purposes and in addition must pay as large a water tax as he will bear; and the excess of income over water expenses is diverted to additional and in many cases needless and extravagant schemes for the illegal expenditures of public money. As an evidence of this fact, note, in every report of the water departments of our communities, the transfers from water receipts to various foreign departments of the public service; to quote one case, a transfer of 23½ per cent.; and another of 32 per cent. of the original appropriation. These transfers show in almost every municipal report, and are violations of law and of great injustice to water takers.

As under the present custom the water expenses are paid entirely by the water takers, any excess of revenue over expenses should be returned to them in the form of reduced rates.

There should be a fair return for the commodity delivered. This, where the water is furnished by the community, should be only the cost of the water; but where a community chooses to disregard its duty and fails to furnish a supply itself, it must bear the added cost of a profit, larger or smaller, to the private company which takes the risk and management of a supply. Private enterprise will see and avail itself of such an opportunity.

and the community must pay the penalty of its neglect either in increased rates or imperfect construction; or finally a very large purchase price, with the consequent large expenses of litigation.

On the idea of putting the cost of the establishment of the water system and the water used for public purposes into the general tax. I will quote from the report of the special committee of business men of Madison, Wis., appointed to consider this matter of water rates and water charges, as follows:

" It will be conceded, we think, that this public use should be charged on the community, not in proportion to the amount of water used for other purposes, but more in proportion to property interests.

" Some cities attempt to distribute or equalize this charge on the community by crediting the water fund with a reasonable amount for each fire hydrant, and for water used by various departments of the city government, school boards, park boards, street sprinkling, etc., and by a system of bookkeeping methods crediting back into the general fund any surplus of earnings thus obtained, but this committee is of the opinion that the cost of water for various public uses should be met by general taxation."

And again from the same committee's report:

"The practice of this department has been, and is, to pay from the water fund the cost of laying all water mains, service connections, cost of meters, etc. Possibly something might be said in favor of assessing these expenses to abutting property, the same as street improvements and sewers are assessed."

If, then, we put the cost of the establishment of the system into the general tax levy, thus taking care of the annually maturing debt and interest, we have left only the maintenance of the system and house connections to be charged to the water takers.

In the case of a number of communities joining in an extensive water supply system under the conduct of the state, as is the case of the Metropolitan Water System of Massachusetts, the amount assessed upon the several communities in that district would be divided into the amount needed for the annually maturing expense of construction and the amount needed for the annual maintenance. The several governments would then put one item into their tax levies and the other into the amount for maintenance to be charged to the water takers. With this

arrangement you have definite figures to consider, for the cost of construction to a given date is shown in dollars and cents, and the annual appropriation gives the amount to be charged to the water consumers.

If you eliminate the large items of debt and interest and extensions you simplify the question of rates to a very large extent. Accepting this method, you include in the annual appropriations for the various departments sums sufficient to pay for the water actually used, and this annual appropriation goes into the amount of the tax levy.

The cost of maintenance is something which can be determined, — so many gallons furnished at so much cost gives the cost per gallon, — and the number of gallons used by any taker determines the amount which he is to pay.

If the calculation of the price per gallon proves to be erroneous and an excessive revenue is collected, the taker should have the benefit in a reduced rate. This change of rate need not be made every year, but could be made after the experience of two or three years should give a reasonably accurate basis of calculation.

If it is possible to determine the amount of water used in the extinguishment of fires, I think this amount should go into the tax levy under the appropriation for fire department; but I am firmly of the opinion that the idea of crediting the water income with the sum arrived at by multiplying the number of hydrants existing in any community by a fixed number of dollars is not a good one and should not be adopted, or if it has been adopted should be abandoned.

Basing the water rate on the cost per gallon multiplied by the number of gallons requires the use of the meter for purposes of measurement; but I think it is generally conceded that to measure water is the only proper method of determining the rate of payment by the water taker. Everything else that we use we buy by weight or measure, whether it be merchandise, clothing, food, gas, or electricity; and why should the quantity of water we use be guessed at?

A certain sum should be appropriated for the installation of meters each year, and this should be included in the expense of maintenance to be apportioned upon the water takers. The

cost of the installation of the meters upon any property should be a lien upon that property, and the city should charge for the actual water which the meter records as passing through it, the charge to be made to the owner of the property and not to the tenant. The owner of the property must settle with his tenant.

The meter should be the property of the city, and the expense of examination should be included in the annual appropriation for maintenance. The charge should be for actual water passing through and be so much per gallon, without any minimum price, or one price for the first thousand gallons and another price for succeeding gallons.

On the question of fire protection in the community we come to the one item in the whole department which causes the most discussion and gives rise to the most conflicting differences of opinion.

Fire protection, because of certain established methods in cases of large manufacturing plants, is divided into what I have called public and private.

While there is a certain element of sentiment in connection with fire extinguishment in that the citizen's home is protected and his household gods are not destroyed, and therefore community governments are exercising their true paternal function in this regard, I am of the opinion that this claim has very little weight indeed and that the question is purely a business and financial one, both as to public and private service.

Under our modern adjustments we find ourselves confronted with two conditions, a demand for an extensive system for the extinguishment of fire in general, and also one sufficient to meet the added demands of a provision for private protection of property by an elaborate system of standpipes and laterals which require to be kept constantly full of water under sufficient pressure to carry to the highest part of the building. As I have stated, and as is generally admitted, the provision for fire extinguishment adds very materially to the expense of the establishment and maintenance of a water plant, and in a large community the provision for private fire extinguishment still further largely increases the cost. If this cost is covered into the tax levy and all interests in the community bear their proportion, the private citizen and the business plant, the wealthy land owner and the

humblest poll-tax payer, the claim of any one that he is entitled to receive something from the community from the fact that he is a part of that community is answered; he receives certain things for which he is entitled and he pays for it in his contribution to the expenses of the community.

Just here the community right and privilege ends; beyond this we enter upon the domain of the individual.

The individual pays for what he uses and only for what he uses at what it costs the community to furnish it to him.

It is a mistaken idea that water is free when you consider it from the idea of the needs of a community. Water in its existence is free, and ample in its supply, take the world over; but its presence is not universal, and to bring it to the barren waste makes it an article of merchandise, and as an article of merchandise, under strict business laws, it must be bought and sold.

I can see no ground upon which to establish a just claim upon any system of water supply to furnish water free for such an enterprise as a business plant. The owners of such an establishment pay for everything else which they use, and why should the community in which they are located furnish its goods free of charge? To the argument that such an enterprise may be of great advantage to the community in which it is located, I answer, that claim rests on the sentimental idea of government to which I have alluded and should have very little weight. In fact, a concession to any private enterprise by which the public expense is increased is illegal, and any tax rate based upon an action of this kind by a community would be vitiated and could be declared invalid.

If the water supply was furnished to the community by a private company, the contention of a public benefit certainly would not hold.

The establishment is benefited with others of the community by the existence of a strong fire department, receiving its benefit in dollars and cents and paying for it with others in its municipal tax; it is alone benefited, financially, in its system of piping, in which the community has no interest or profit, and therefore should not be called upon to bear any portion of the expense. The purpose for which this private protection is established is to limit to the minimum any loss of profit by an interruption of

the business because of fire. This is entirely a personal and selfish interest, and therefore the public should not be called upon to bear any portion of the expense. To the suggestion that an interruption to the business would be a loss to the community, I answer that while this may be true I cannot see that it is any reason for allowing a constant premium to the individual in the way of free water for a series of years, at the expense of the community, in exchange for such a contingency.

The concession might with justice be made that when the piping system was established it should be filled by the department on the ground that the water simply stands in the pipes and is not therefore a constant demand upon the system and consequently not a cost to the community. The private company saves in insurance charges by a well-equipped fire department and the piping system. This saving is all its own.

For this former benefit he pays his proportion with all the other values of the community, and for the latter expense he secures all the benefit, which is perfectly proper.

The insurance companies receive the benefit of the well-equipped fire department for which the citizens tax themselves, and also the benefit of the protection afforded by systems of piping, and therefore I do not see where they enter into the consideration at all.

It is unjust to the citizens of a community to claim that the officials of a water system should be obliged to be detectives to make sure that the piping systems are in good condition and that no use is made of them other than for fire extinguishment. Evidencies of an improper use of these systems of piping, and defects in construction and condition, are frequent and ample, and the individual is wronging the community when he obliges it to go to the expense of detecting these defects. If a group of manufacturing companies should combine to put in a plant for their collective use, it is certain that all these points would be most carefully watched to see that each individual plant was in first-rate condition and that no one concern obtained any advantage at the expense of others in the group. Surely the community is entitled to as fair treatment as a combination of mercantile interests.

Thus far I have considered the subject from the point of view

of a public or community control, but where the supply is furnished by a private company most of what I have said still holds true. The principal difference is that while I claim that under the community control the citizen should have his service at cost, in the case of the private company no such contention can be maintained. The principles remain the same; the details of the relation between the company and the community differ.

The relations between company and community are in the way of franchises for rights through its streets and ways, and compensation for public purposes and for fire department service.

For the private citizen the burden falls more heavily under a system of private control than under a municipally controlled one, for under the former management maturing debt, interest, depreciation, maintenance, including salaries and repairs, together with extensions, must all be assessed upon the water takers, and to this sum must be added a profit for the stockholders.

Water used in the public service would in this case be paid for in the tax levy and the individual service paid direct to the company. Under both forms of administration, however, the basis of cost and quantity used should fix the rate of collection. In all cases the meter is the proper measure of quantity, and the cost per gallon, including all the items heretofore enumerated, the unit of value.

I am aware that the method which I have outlined, of including all except the maintenance in the tax levy, is at variance with the general practice; yet I think it is the fair and just method, for as at present administered the water taker pays more than his proportion of the expense, as the large holder of real estate made very much more valuable by reason of the water system does not pay any portion, but the water taker pays all and in addition contributes to the various schemes for general municipal expenditure beyond the amounts allowed by law. I believe it to be the bounden duty of all connected with the administration of public affairs to use every effort to have the administration of systems of water supply improved along these lines.

PUMPING BY ELECTRICITY.

BY F. H. PITCHER, C.E., CHIEF ENGINEER, MONTREAL WATER AND POWER COMPANY.

[*Read September 10, 1903.*]

The rather high-sounding title of this paper is not to be taken as a fair indication of its scope. At the outset, in order to clear the author, it should be stated that it was none of his doings. Mr. Kent, our genial secretary, mildly suggested to the writer, on meeting him in the city last July, that a paper on some subject connected with water works in this district would be acceptable to the Association at its convention in Montreal. It was mentioned, by an unhappy chance, that there were some large electric pumps operating in connection with the water supply of the outlying municipalities of this city with which the writer was interested. Forthwith a few days later an innocent-looking letter arrived, making the author responsible to the convention for a paper on this large field of engineering. Such few observations as may be presented here will, it is hoped, be of some interest to the members; but they cannot and do not aspire to cover the range indicated by the title.

Our larger cities in the East, like Montreal, Toronto, Hamilton, Ottawa, Quebec, etc., are more favorably situated perhaps for obtaining cheap electric power than corresponding cities in the New England States and others along the Atlantic seaboard. This is on account of their proximity to large water powers, capable of commercial development. None of these cities is, everything considered, in a better position in this respect than Montreal. Its population, manufacturing and kindred industries offer a ready market for a larger amount of power, while its proximity to the developed and undeveloped powers on the Richelieu, St. Lawrence, Ottawa, and Shawinigan rivers makes it possible to supply the demand on a commercial basis.

The following are the principal developed water powers deliv-

ering under normal conditions of operation power to Montreal approximately as follows:

At Chambly, Que., 21 miles from city,	20 000 H. P.
At Lachine Rapids, Que., 5,miles from city,	14 000 „ „
At Shawinigan Falls, Que., 80 miles from city,	6 000 „ „

The latter is a 30,000 horse-power development. The remainder of the power is being absorbed now by the industries at Shawinigan Falls, or will, in all probability, shortly be taken up by this city as well as by other towns and cities along the line.

All of these powers are capable of expansion, and are even now being extended so that there is little doubt that twice the present amount of electric power from water powers will be available in Montreal in the near future.

The principal undeveloped powers near the city are:

Back River, 6 miles from city,	50 000 H. P.
Soulanges Canal, 30 miles from city,	25 000 „ „

Another important available water power of 50 000 horse power has been developed at Massena, N. Y., approximately sixty-five miles away.

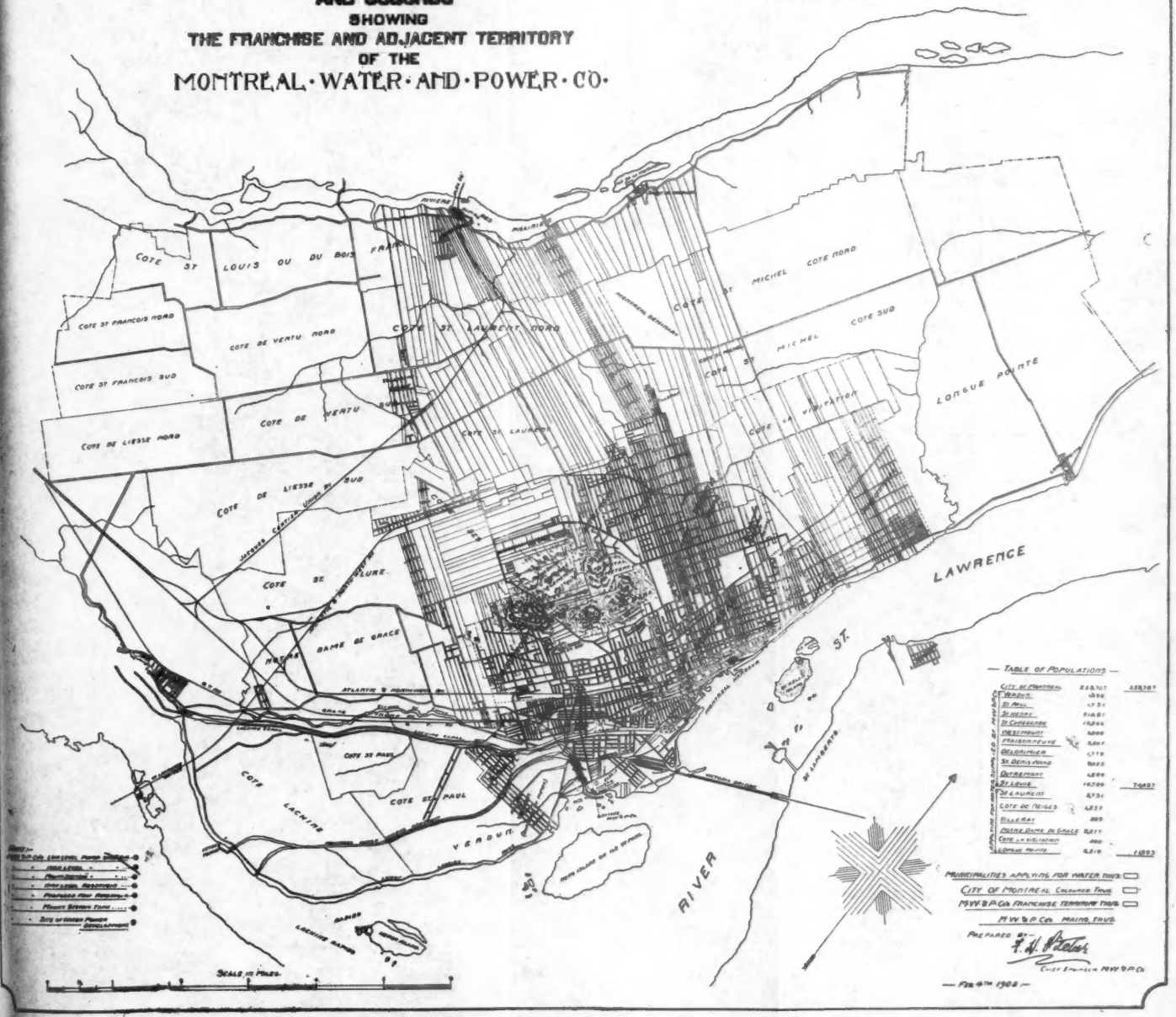
It is, therefore, not unnatural that electricity should form an important factor in the motive power of Montreal.

As a matter of fact, for factory and machine shops drives, elevators, street railway power, pumping, etc., electricity from adjacent water powers is largely used at present in Montreal, and by proper management there is every reason to believe that its use in the near future will so increase that present local steam plants will be retained mainly as auxiliaries and reserves. Under normal conditions all public street lighting and practically all indoor lighting in this city is at present furnished by water powers.

BRIEF DESCRIPTION OF MONTREAL WATER AND POWER COMPANY'S SYSTEM AND GROWTH.

The water-works system making the greatest use of electric pumps in Canada, if not in America, is that owned and operated by the Montreal Water and Power Company. On this account, for the purposes of this paper, a brief description of the general system of that company and mention of its growth may not be out of place. It is proposed to limit, for the most part, the present

MAP
OF THE
CITY OF MONTREAL
AND SUBURBS
SHOWING
THE FRANCHISE AND ADJACENT TERRITORY
OF THE
MONTREAL · WATER · AND · POWER · CO ·



paper to a discussion of the problems involved in the large electric pumps used by the above company.

The city of Montreal proper is bounded on one side by the River St. Lawrence and on all of the three other sides by independent outlying municipalities. These extend from the river on the west side, around behind the mountain and the city to the river again on the east side. From river to river, by way of the shortest main supply pipe which could be laid for them all, is over 15 miles, and an altitude of over 600 feet above the river is reached on the way, in one of the principal municipalities.

These municipalities are now the towns of Cote St. Paul, Verdun, St. Henry, Ste. Cunegonde, Westmount, Cote des Neiges, Outremont, St. Louis de Mile End, St. Denis Ward (now a portion of the city formerly the town of Cote St. Louis), De Lorimier, and Maisonneuve (see Plate I).

In 1891 the Montreal Island Water and Electric Company, now incorporated as the Montreal Water and Power Company, obtained franchises for a long term of years to supply all these municipalities with water; with the exception of Verdun and De Lorimier, which have since come in, and Cote des Neiges, now negotiating with the company for its water supply. Two of these towns, Ste. Cunegonde and St. Henry, had at that time their own supply from the present source of the above company. The others either had no public supply or obtained their water through large meters from the city of Montreal.

The first step in organizing a general supply system was naturally to connect all these municipalities together in such a way that they would obtain their supply from the most available and feasible source. The source decided on was the St. Lawrence River above the city, thereby utilizing the 36-inch intake pipe of the old Ste. Cunegonde water works. The water is taken at a point 1 650 feet (approximately) from the shore and is pumped directly into the mains.

The work of connecting up the different municipalities was completed in 1898, and the present supply system established. From the nature of things three lifts were found necessary, one of 200 feet from the river forming the main supply. This supply is pumped through force mains approximately 6 500 feet long, and then distributed through the gridirons of the towns in front of

the mountain lying " below the hill " and at only a slight elevation above the average river level. The population receiving its supply from this lift is approximately one-half of the present total population supplied. In order to supply most of Westmount, and a large part of the territory behind the mountain, a second lift of 270 feet was established. The pumps at the 200-foot level take their water from a catch-basin of relatively small capacity, which receives the surplus water of the low-level system. These again pump directly into a reservoir of 8 000 000 Imperial gallons capacity (approximately) at an elevation of 470 feet, and also into the mains, there being no separate system of rising mains. This lift supplies practically all the other territory both in front of and around the mountain (see Plate I).

The pressure for the low territory like Maisonneuve, etc., is suitably controlled by regulators. This is, of course, not the most economic final plan, but at present the amount of water let down through the regulators is not over 25 per cent. of the whole supply. A plan to establish a low-level reservoir at a suitable elevation and connected with the back territory by a low-level gravity main around the western spur of the mountain is now under consideration. The execution of this plan will become important as the " back " territory grows.

Besides the two lifts mentioned, there is a third, established in 1898 for the supply of a few houses on top of the Westmount Mountain. This is a lift of 180 feet (approximately), and as yet of small importance in point of size. To-day over 80.000 people are being supplied in this way.

Seven and one-half million Imperial gallons are consumed daily, and the pumping at all three stations is done by electric pumps. The low-level station is at the river in St. Gabriel Ward of the city proper, and is called St. Gabriel Station. The intermediate station is on Clarke Avenue, Westmount, at an elevation of 200 feet, and is called the Clarke Avenue Station. The remaining station is at the reservoir and is called the Mountain System Station.

The pumps at the low-level station in 1898 were two in number — one an old-type crank and fly-wheel quadruple Holly of about 750 000 Imperial gallons capacity and the other a duplex direct Snow steam pump of about 3 000 000 Imperial gallons capacity, (see Fig. 1). At Clarke Avenue there were two direct duplex

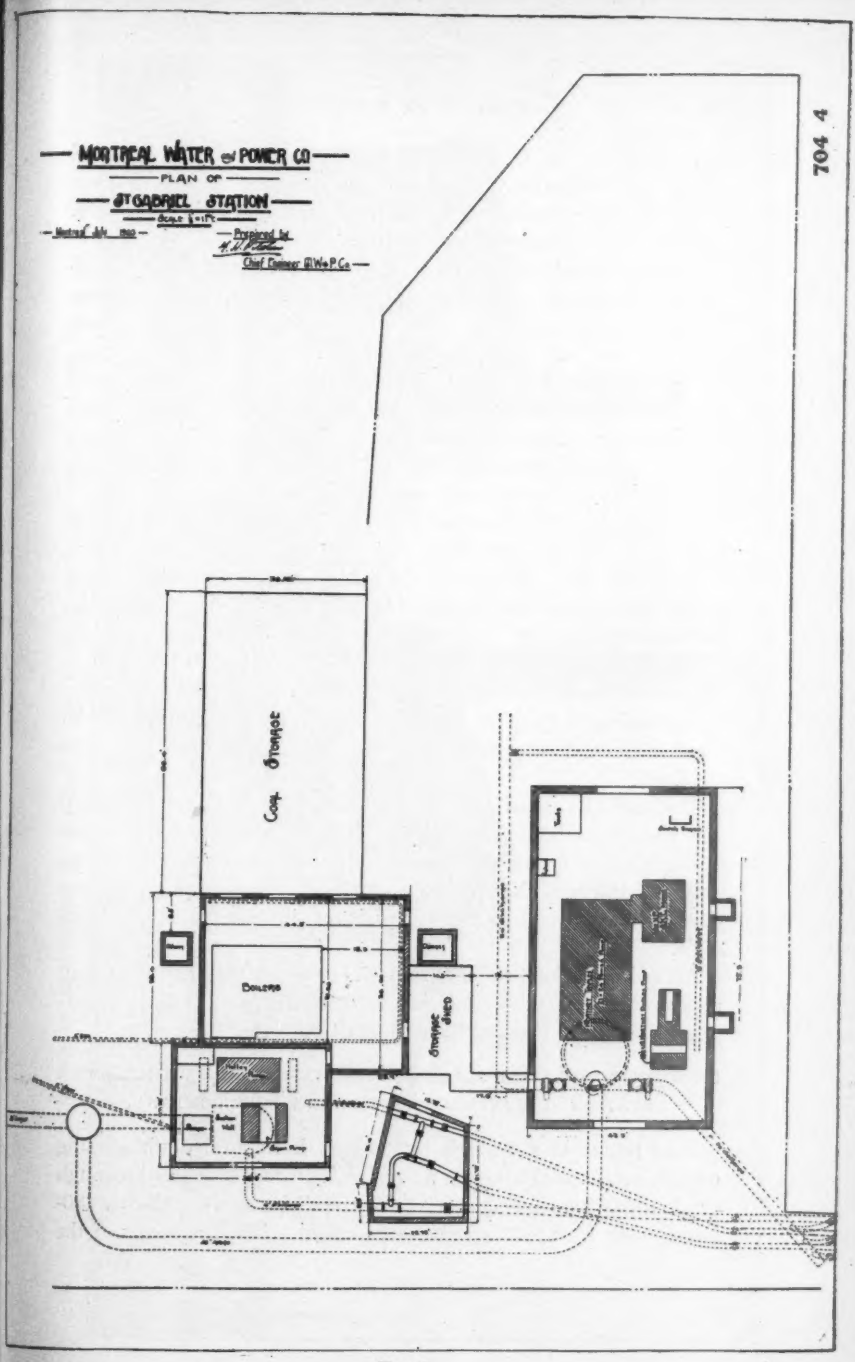

MONTREAL WATER & POWER CO
PLAN OF
ST GABRIEL STATION
Scale 1=10'
Prepared by
Chief Engineer M.W.& P.Co.
704 4
Coal Storage
Boilers
Storage Shed

FIG. 1.

steam pumps; one of 2 000 000 and one of 1 000 000 Imperial gallons daily capacity. The larger pumps were added to each station as the consumption in the front grew and before the back territory was connected to this source.

The population had more than doubled in the four years preceding the completion of this work of connecting up all the towns. The distribution systems of the towns were extended during that period in even a greater proportion; so that, when finally the pipe system was ready to supply the whole territory, it was apparent that additional pumping capacity was necessary at the lower station if the company was to supply all the water from its own source. An additional capacity of 5 000 000 Imperial gallons was then decided on for the lower station.

At that time the Chambly and Lachine Rapids water powers were in successful operation and offering power at attractive rates in the city. Moreover, the load curve of the electric companies had then a severe peak between 4 and 8 P. M., due to the incandescent lighting. This peak during the winter nearly reached the limit of their full capacity. During the other 20 hours there was more than three times as much unused power. Accordingly, by arranging to take the greater portion of power during the 20 hours outside of the peak load, very reasonable flat rates were obtained.

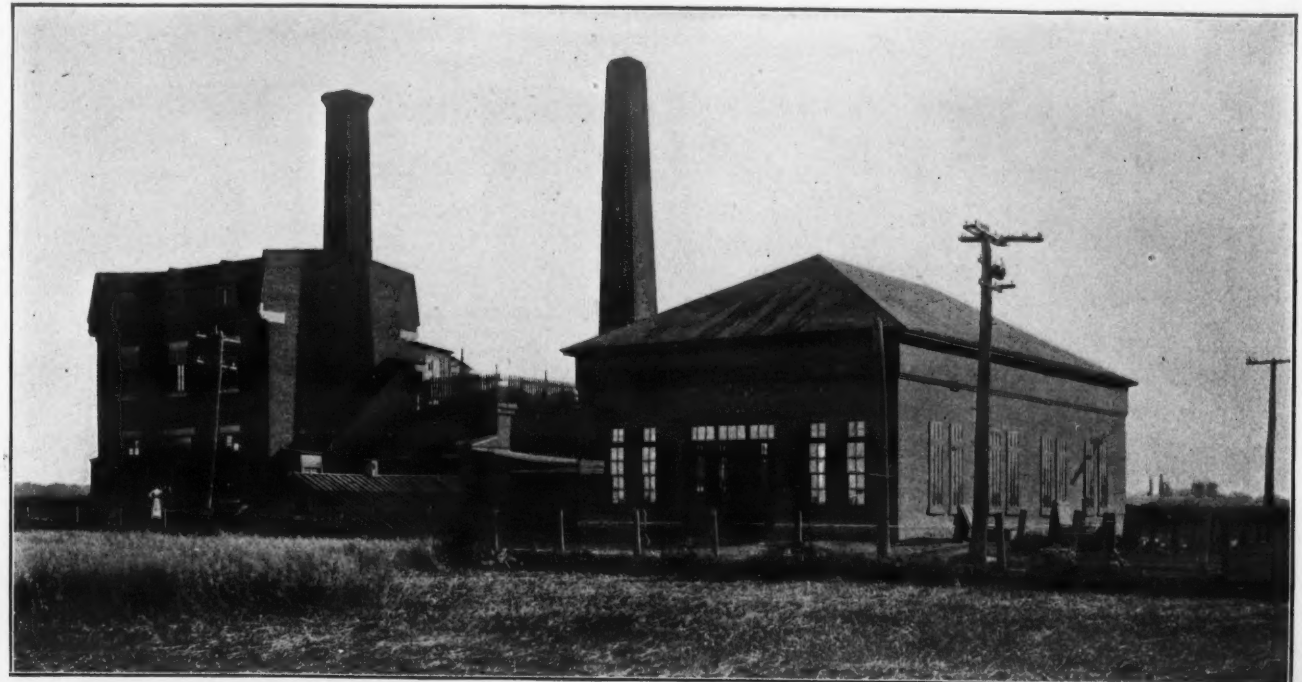
The capital cost of a 5 000 000 Imperial gallon electric pump was then considerably less than that of a steam plant of equal duty reckoned on a steam basis. The estimated attendance was only two-thirds of that for a steam plant. Electric pumping was therefore decided to be worth trying on this comparatively large scale.

Accordingly the 5 400 000 Imperial gallon triplex electric pump now running at the lower station was installed, and put into operation in 1899 (see Figs. 1, 2, and 3, and Plate II).

DESCRIPTION OF FIRST ELECTRIC PUMP INSTALLED AT THE LOWER STATION OF MONTREAL WATER AND POWER COMPANY.

This pump is a 21-inch by 24-inch horizontal double-acting outside center packed power pump, and is direct connected through single reduction gearing and a " Worrall " friction clutch to a 480-horsepower S. K. C. synchronous motor. The frequency of the

PLATE II.



VIEW OF ST. GABRIEL STATION — NEW ELECTRIC STATION IN FOREGROUND AT RIGHT.

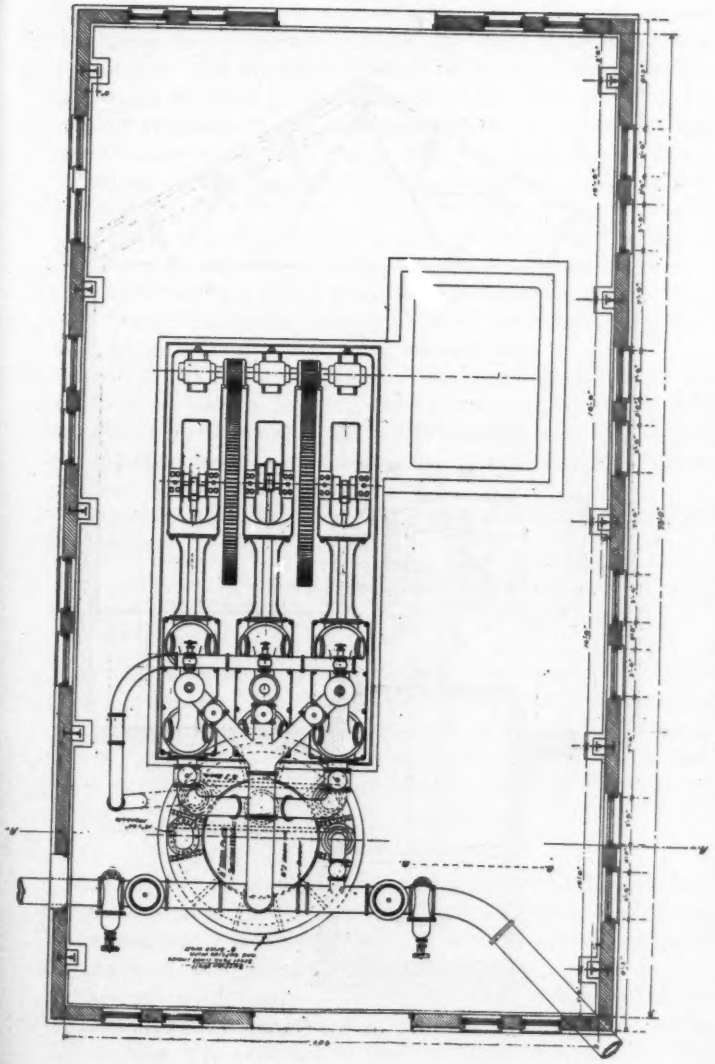


FIG. 2. PLAN OF ST. GABRIEL STATION.

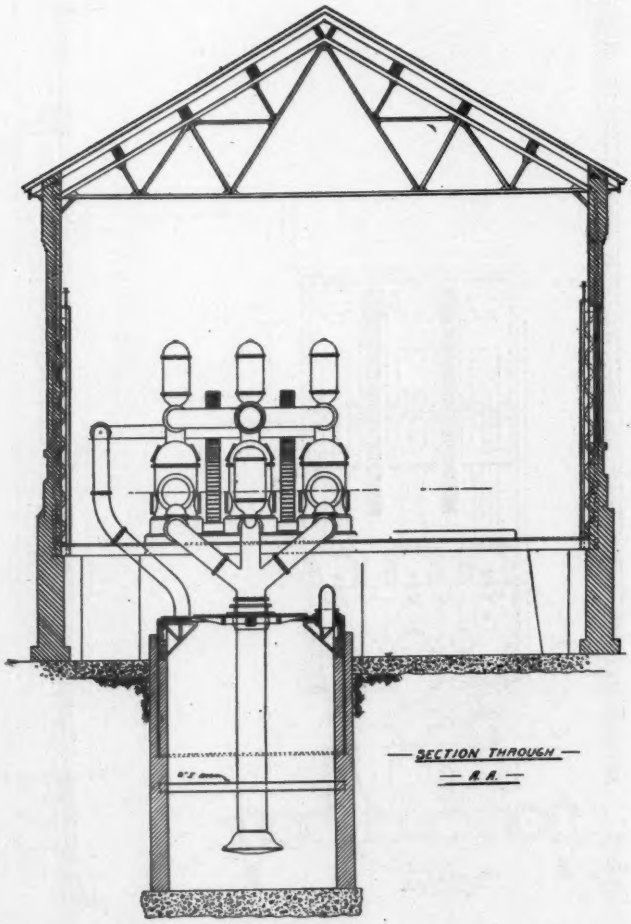


FIG. 3. SECTION OF ST. GABRIEL STATION.

power was 66 cycles per second and a 22-pole machine was adopted. This gives the comparatively low motor speed of 180 revolutions per minute. A piston speed of about 80 feet per minute was fixed, and single reduction gearing adopted with a ratio of 8.88. The gearing arrangement was made symmetrical by using two large gears on the crank shaft, one on each side of the middle pump. There are six main crank-shaft bearings, and consequently no overhanging cranks. The jack shaft carries two pinions engaging with the gears. This shaft is carried by pillow blocks resting on the frame of the power end.

The valve area is 65 per cent., there being 36 3½-inch valves in each deck. The water chambers are of the externally smooth vertical, cylindrical type, having internal ribs.

The rigid frame carrying the jack shaft and crank shaft is tied to the pump ends in the usual way by heavy castings, which form the guides for the cross heads. This makes a very symmetrical and pleasing design, with at the same time almost a maximum compactness (see Plates III and IV).

Other principal data concerning the power end of this pump are as follows:

2 C. I. Gears 178″ pitch diam. 160 Teeth 3.494 Circular pitch.
2 C. I. pinions 20.12″ „ 18 „ „ „ „
Reduction ratio, 8.88.

Average speed of pump shaft has been maintained at 21 revolutions per minute. The three-throw crank shaft is a steel forging, 10 inches in diameter through journals and crank pins, and 12 inches diameter at gear hubs; over all length 16 feet 2 inches. Steel pinion shaft is 7½ inches diameter through bearings, 9½ inches at pinions.

OTHER DATA.

Rectangular locomotive type connecting rods, 6 feet long center to center. Cast-steel cross heads, circular brass shoes, cross-head pins 7 inches diameter. The main bearings consisted originally of solid phosphor-bronze boxes and journals as well as the crank-pin journals. The bronze plunger rods are 4¾ inches diameter. The three pinion-shaft bearings were of the spherical self-aligning type common to electric generators and motors. They were babbited. The water end was provided with the usual

suction run around pipe, a discharge air chamber over each uptake, and one main suction air chamber. Discharge pipe is 20 inches diameter, suction 24 inches diameter. Separate suction and discharge stop gates are provided for each pump, so that any or all pumps could be cut out at will. In addition, a main hydraulic bypass valve was provided for starting and also for reducing the load on the motor during the four hours of the peak of the load of the electric power company. By means of this valve the pressure is held at any desired point below that of full load.

There was also provided an 8-inch spring relief valve of the Ashton type for each pump. These remained set at the same maximum pressure. There are, of course, the usual main discharge, check, and foot valves. A feature of this installation was a new steel intake well, or rather tank, below high-water level in the river, and a 36-inch steel intake pipe connection between this and the 36-inch wooden intake pipe to the old station.

The air-charging device is the usual water column and air valve arrangement.

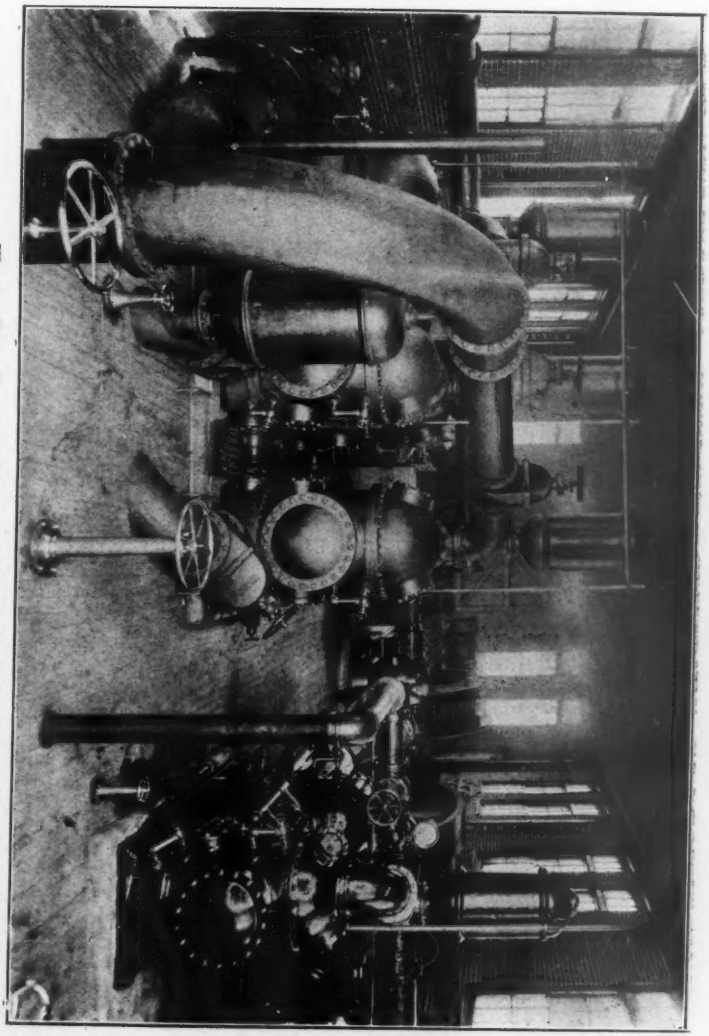
BRIEF DESCRIPTION OF THE MOTOR.

The motor, as above mentioned, is a 480-horsepower two-phase 66-cycle 2 400-volt synchronous machine of the S. K. C. type, that is, a stationary field and armature with a revolving inductor. There are then nor evolving coils whatever, merely a cast-iron spider carrying laminated steel pole pieces. A feature of this machine is its large air gap as compared with induction motors. This gives perhaps greater security in its operation.

The fields of this machine are excited in the usual way by a belted 10 K.-W. D. C. generator. This little machine is shunt wound, and has a rheostat in both field and armature by which the exciting current of the motor is adjusted. The starting motor is a small 15-horsepower S. K. C. two-phase 500-volt induction machine, which can be thrown in or out of gear with the 5-foot 4-inch cast-iron spur gear carried on the motor shaft. The speed of the starting motor is regulated by a water rheostat in its motor, by means of which the large motor, when in mesh with the starter, is brought into synchronism with the line.

There are the usual ammeters, voltmeters, etc., on the switchboard, as well as fuses, lightning arresters, etc. No wattmeters

PLATE III.



WATER END VIEW OF ELECTRIC PUMPS AT ST. GABRIEL STATION.

were provided on account of the power being bought on a flat rate based on the maximum load.

The lower voltage required for the starting motor necessitates two transformers, one in each phase.

During the four years this machine has been operating, the company has had every reason to be satisfied with the motor itself. One stator coil was burned out some years ago, due to the motor going out of step on a short circuit and not being taken off the line in time.

As long as normal conditions are maintained on the line this machine runs with little trouble. The type, and more especially this particular machine, has not sufficient regulation to stay in step when a sudden drop in line voltage of any considerable amount occurs.

Unfortunately, however, for this type much auxiliary apparatus is found to be necessary. A flat on the commutator of the exciter, not quite enough resistance in its fields, may cause, and has caused in this case, a shutdown of serious import. An extra armature is carried for the exciter; but this part of the apparatus has been uniformly found to be the weakest in the electrical equipment. Trouble has also been experienced with the starting motor transformers. Lightning, not grounded, burned them out at first. They were then provided with switches which enabled their primaries to be taken off the line when not in use. The above accident caused a shutdown of nearly a day.

The burning out of the little transformers for the synchronizing lamps has also shut the pump down.

On the whole, the points against a synchronous motor from the user's standpoint are found almost entirely in its auxiliary apparatus. On the other hand, these motors are virtually more efficient than their induction rival, inasmuch as the central station, or people selling the power, often take account, in fixing the rate, of the power factor of the motors they operate. By over excitation, as is well known, the power factor can be brought practically to unity; in other words, the wattless current is wiped out. In that case the consumer gets all the power he pays for; in the other only, say, from 70 to 90 per cent., depending on the ratio of the true to the apparent watts of the motor.

If no account of this is taken by the central station then every-

thing is in favor of the induction motor. However, more will be said about this type of machine when describing the Clarke Avenue plant.

To return to the operating of the pumps:

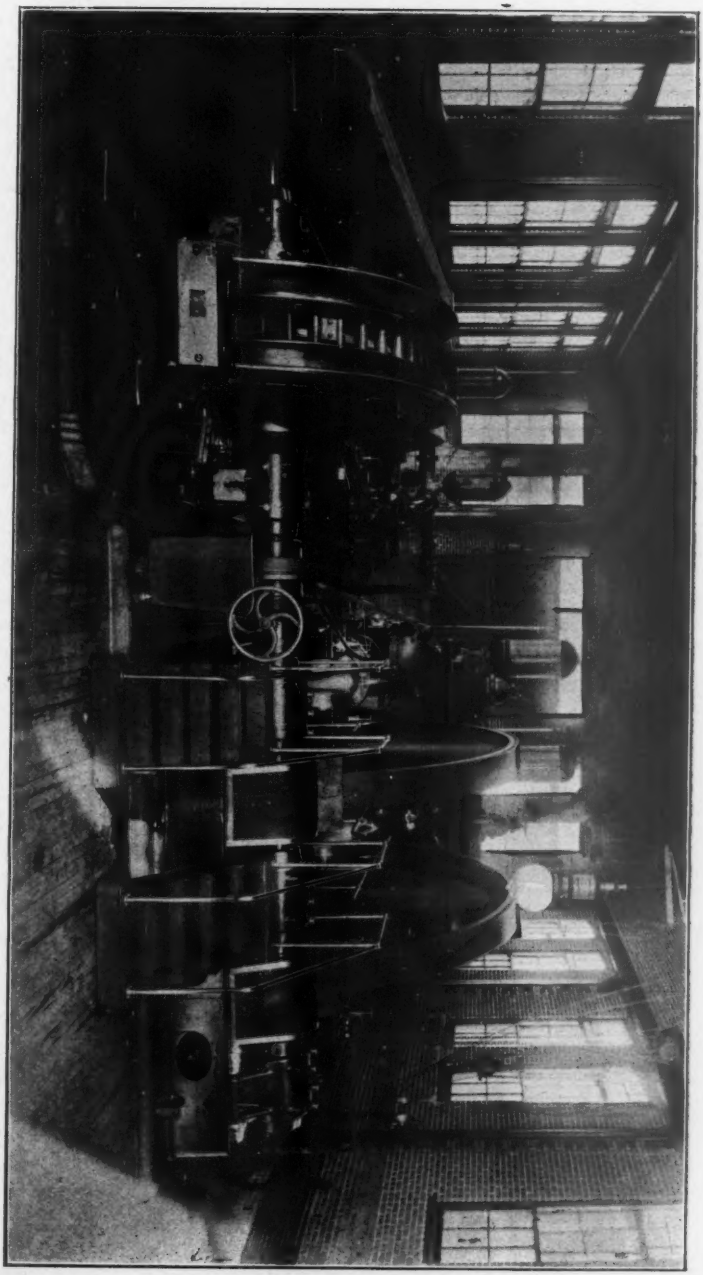
In order to reduce the noise of such heavy and comparatively high-speed gearing (980 feet per minute) to a minimum, raw-hide pinions were at first adopted. These were built up in the usual way with layers of raw-hide on a cast-iron center and held between shrouds in one piece with the centers. Steel bolts were inserted from end to end and an inch or more extra raw-hide face provided to allow for taking up shrinkage. These, when they ran well, were very noiseless and smooth, but it was soon apparent that they would not answer. The middle of the tooth seemed to spring away from the work and leave the ends near the shrouds to do most of it. This caused excessive wear. Moreover, the shrinkage with this raw-hide was so great that fiber had to be inserted at the ends in order to take up. Finally it became impossible to take up the shrinkage. The raw-hide seemed to loosen between the shrouds and the pinions failed by cracking at the root of the teeth.

While this was going on the vibration in the large gears was extreme and the noise excessive.

It was essential to start this pump again without any unnecessary delay. Shrouded machine-moulded pinions were therefore put on and are running to-day, but, as might be expected, with considerable noise.

The wear has also been great, and the writer has concluded to abandon the two sets of gearing, substituting therefor one set in the pit next the motor. The frames are fortunately wide enough to allow a 21½-inch face, which will be ample for the 300 horse-power now transmitted by those gears. The crank shaft is also sufficient to allow this change. It has, moreover, been decided to get 10 per cent. more water out of that pump than at present by reducing the reduction ratio. A single pair, consisting of a machine-cut cast-iron gear and machine-cut steel pinion, is now on order for this pump.

Another source of trouble at the start was found in the phosphor-bronze boxes. There was too much anxiety for the water from this pump to give these a fair chance to come to a surface. They



POWER END VIEW OF ELECTRIC PUMPS AT ST. GABRIEL STATION.

took this occasion to heat badly and seize, and therefore had to be afterwards lined with babbit. Thus equipped, this pump has run without any extraordinary repairs since October, 1899, to the present time.

EFFICIENCY TEST.

By testing this plant with a Weston direct-reading wattmeter on the motor circuit, and indicating the water cylinders at the pump end with Crosby indicators, an overall efficiency as high as 85 per cent. from electric line to water has been observed. There is, however, considerable difficulty in observing the electric input with these sensitive wattmeters. This is due to the irregular oscillation of the needle. But there is every reason to believe that the above figure is within 2 or 3 per cent. of the truth.

Taking the average price of coal in Montreal, and the price per horse power of electric power, we obtain a duty from this pump on a basis of foot pounds per 100 pounds of coal, about 87 000 000.

The writer entered the company as chief engineer in September, 1899, while this pump was making its trial runs. When it was finally started it was at once apparent that the intermediate station on Clarke Avenue was not able to carry the additional load and thereby furnish all the water for the high levels and back territory. The boiler and chimney capacity were added to as a makeshift until something more permanent could be done, as it was at once made clear that the direct-acting duplex pumps at this station were neither sufficiently large nor efficient to do the work required. It was also clear, at the same time, that there was not sufficient force main capacity even for the present requirements between the lower pumping station and Clarke Avenue Station.

At the lower station, with the new pump running, the pressure was 145 pounds and the lift only 200 feet. The new electric pump was designed for 120 pounds pressure.

It was, therefore, decided to increase the capacity of the force mains and that of the pumping plant at Clarke Avenue. Accordingly, a new 24-inch main was laid to St. Henry, and 14-inch and 16-inch mains in that town — the former one across the town from east to west and the other straight north and south to Westmount. This gave three force mains, 12, 14, and 24 inches

in diameter, about 6 500 feet in length from the St. Gabriel Station to the St. Henry and Ste. Cunegonde gridirons. In passing, an interesting feature of laying force mains from this station to the main system is the necessary crossing of the Lachine Canal. The pipes have to be laid to give a clear 20-foot water way; and the bottom of the canal, where the company's crossings have been made, is a *quasi* quicksand. The work is, of course, done at the low water during the government repairs to the canal in the spring, but the material in the bottom renders coffer damming and trenching difficult.

This new work when completed reduced the pressure to 85 pounds, with 5 500 000 Imperial gallons consumption. It has now worked up to between 93 and 94 pounds.

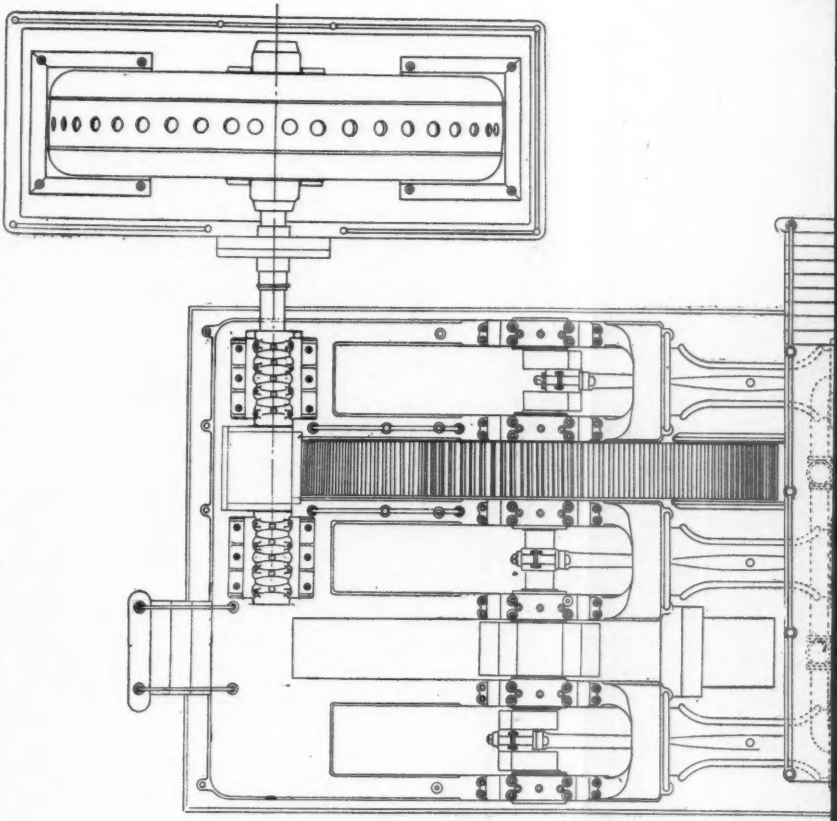
Besides the consideration of economy, there was another and perhaps a more important factor to consider in deciding on the type of pump for Clarke Avenue. The surrounding property is of a purely residential character and of a good order. The pumping station is on a very steep hillside. The smoke and hauling of coal up the hill incident to the operation of a commercial steam plant were much complained of by the neighbors, and proceedings were threatened. Knowing, however, that it was a choice between some noise and vibration in the immediate vicinity on the one hand, and smoke and dirt over a broader area on the other, the choice fell to an electric plant.

THE CLARKE AVENUE ELECTRIC PUMP,

(see plates V, VI, VII, VIII.)

The chief considerations here in connection with an electric plant were, after durability and efficiency, the avoidance of undue noise and vibration as above mentioned. Accordingly a pump was designed and installed in place in August, 1901, much like the first one in general type, but heavier and better built. Many mechanical changes were made, most of which were found to be improvements. Types of rotary pumps then on the market were considered but discarded.

The capacity of this pump was fixed to begin with at 4 500 000 Imperial gallons. This gives easily an additional 1 750 000 over the old steam plant at this station. The new pump is, however, designed to run up to 7 000 000 Imperial gallons by merely chang-

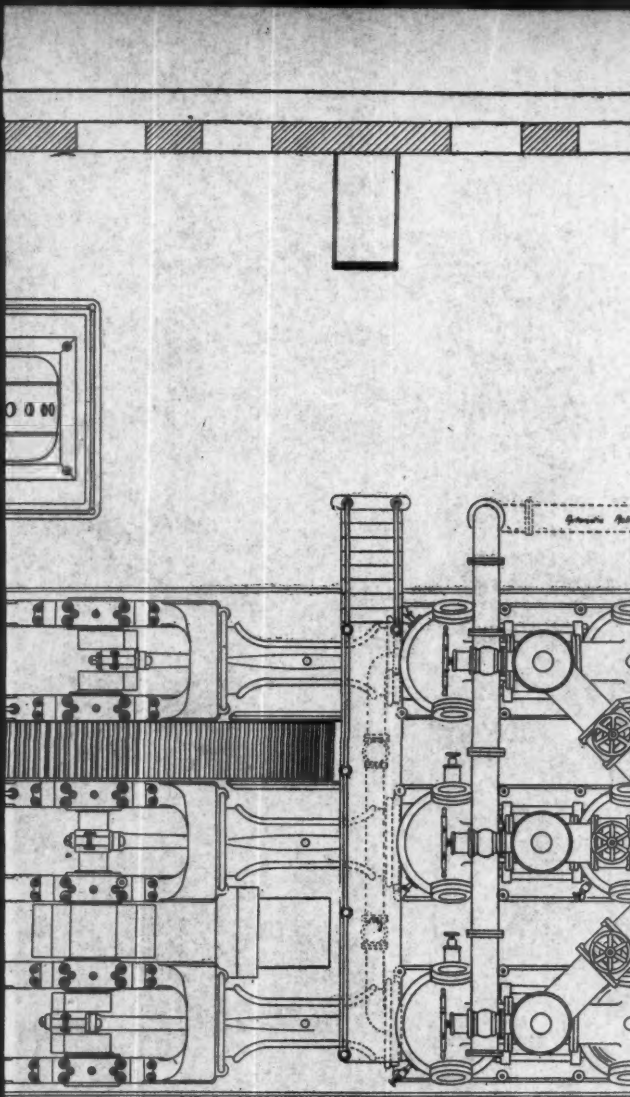


19½ × 24 TRIPLEX POWER PUMP, C

MONTREAL WATER

Montreal Aug 29, 1903

SCALE



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MONTREAL WATER and POWER Co

SCALE ½ = 1 FT.

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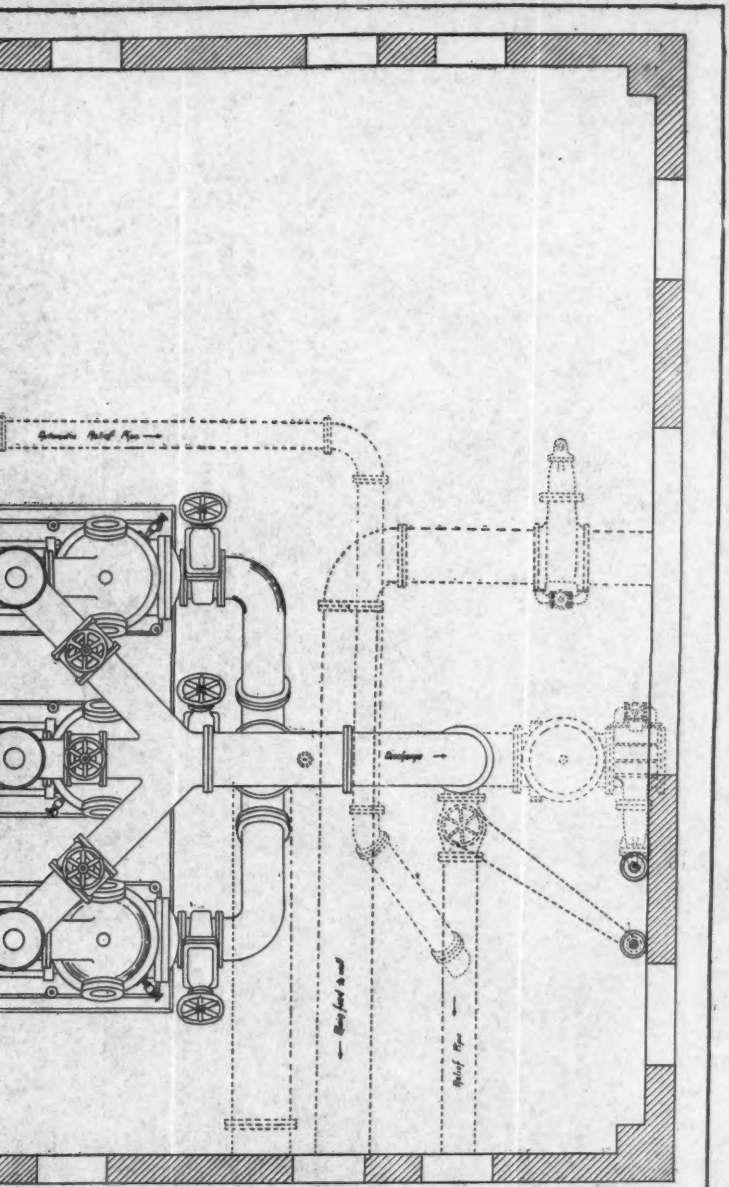

VE STATION

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Prepared by
F. H. Peters Chief Engineer

ing the pinion. This is ample to provide for normal increase at this point for some years.

In event of a low-level reservoir being established at the proper level for the supply of the greater part of the territory, a heavier pump than the first one would be necessary. At the same time, such a large one would then not be required at Clarke Avenue. Accordingly, this pump was designed all around for a working pressure of 175 pounds, with a view to removing it to the river for the proposed new service. Its present head is about 118 pounds. This brought its weight (exclusive of motor) up to nearly 375 000 pounds, the lower pump being about 275 000 pounds. The chief differences between this pump and the other are, first, the gearing, which consisted of mortise gears and steel pinions; steel babbited boxes instead of phosphor bronze; marine crank ends; pillow blocks adjustable on frames; steel plunger rods instead of bronze and the carrying of these rods through the cylindrical plunger and securing by a taper in front and a locked nut at the back were other differences. There are also other minor differences.

This pump is a 19½-inch by 24-inch horizontal triplex, and the general arrangement of gearing was the same as the first. The motor being built for a slighter slower speed, viz., 160 revolutions per minute, allowed for the same piston speed with a correspondingly smaller reduction ratio. The gearing consisted of 2 mortise wheels carried by the same crank shaft, 140 maple teeth, 200.52-inches (16 feet 8½ inches) pitch diameter, 18-inch face, 4½-inch circular pitch (these teeth were hand dressed); and 2 machine-cut steel pinions carried by the same jack shaft, 25¾-inch pitch diameter, 18 teeth. Reduction ratio 7.88. The steel-forged three-throw crank shaft is 11¼ inches diameter through crank pins and journals and 13½ diameter at gear hubs; overall length 16 feet 11 inches. Distance between gears is 6 feet 3 inches.

Arrangement of bearings, etc., is as with the other pump. The jack shaft is connected with motor through a 500-horsepower 48-inch Worrall clutch. This clutch consists merely of a cast-iron disc keyed to one shaft which is gripped between shrouds keyed to the other. The usual lever and toggle joint link is employed to operate it. The disc and shrouds are beveled, which ensures accurate centering. On the whole, this clutch has been found most satisfactory. There was not the same necessity for a clutch

in this case as previously, on account of an induction motor being adopted, but a friction clutch of some suitable kind is considered almost indispensable with power pumps of this size.

The permanent induction motor for this pump, which was contracted for in 1901, was, at the time, the largest of the type evee built. There is only one other as large, and that is a duplicate built for the electric pump of the city of Montreal now being erected.

This machine, being a very special one of extraordinarily slow speed, was naturally late in coming. A temporary drive was therefore arranged so that the pump could be started in the summer of 1901 (see Figs. 4 and 5). This consisted of a 200-horse-power three-phase 600 revolutions per minute alternator, belt-geared to a 10-foot pulley on a temporary jack shaft, erected on timbers from the permanent motor foundation. The regular clutch was used at this time and proved a very necessary part of the equipment.

This arrangement had a pinion-shaft speed of 100 revolutions per minute, which brought the load within the capacity of this temporary motor. This drive ran from August 1, 1901, to April, 1902, or eight months.

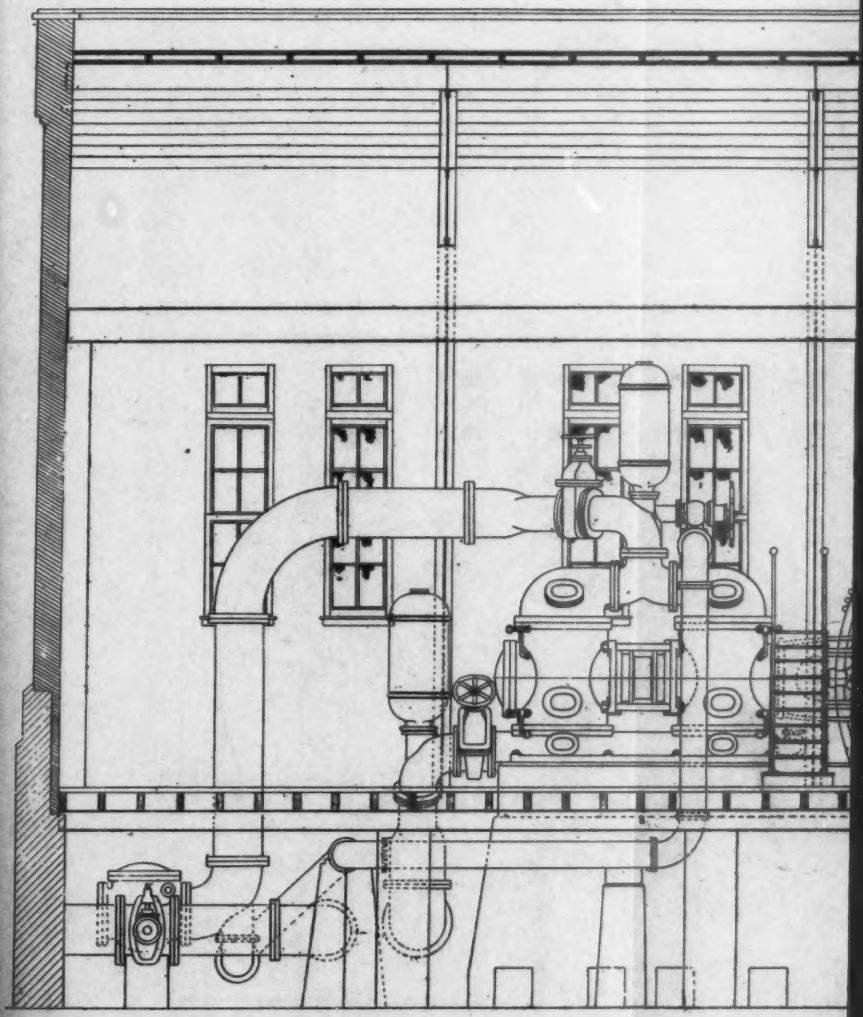
When this pump was first started it seemed satisfactory. The gearing made only a slight rumble and there was very little vibration. It seemed as if the ideal in electric power pumps had been reached. Soon, however, it was noticed that the wooden cogs were fraying, and the action of the gears consequently became less smooth. It was soon — in less than six weeks — necessary to re-cog these gears. This was done by taking one out and running the pump in the meantime with the other pair. After the first one came back, and while the other was away to be re-cogged, it was noticed that the gears ran better and lasted longer with one pair than with two. On investigating it was found that at the periphery of these 17-foot wheels there was a spring between them of over $\frac{1}{4}$ inch, when a tangential force equal to 150 horse-power at 100 revolutions per minute of the jack shaft was applied. This was, of course, due to spring in the crank shaft. When the stresses on the gears are considered in relation to the resultant of the three-crank effort curves, it is at once apparent that there is, during every revolution, a fluctuating load between these gears. This is brought about by the outside cranks, whose load is, from the

MONTREAL WATER and

SIDE ELEVATION - 19½ x 21 TRIPL

CLARKE AVE. STATI

Montreal Sept. 5, 1903 SCALE 1" = 1

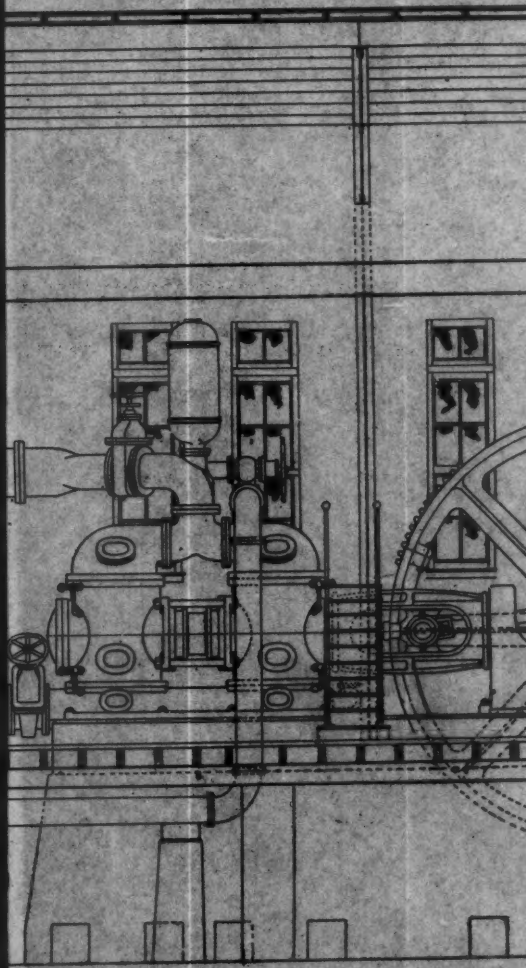


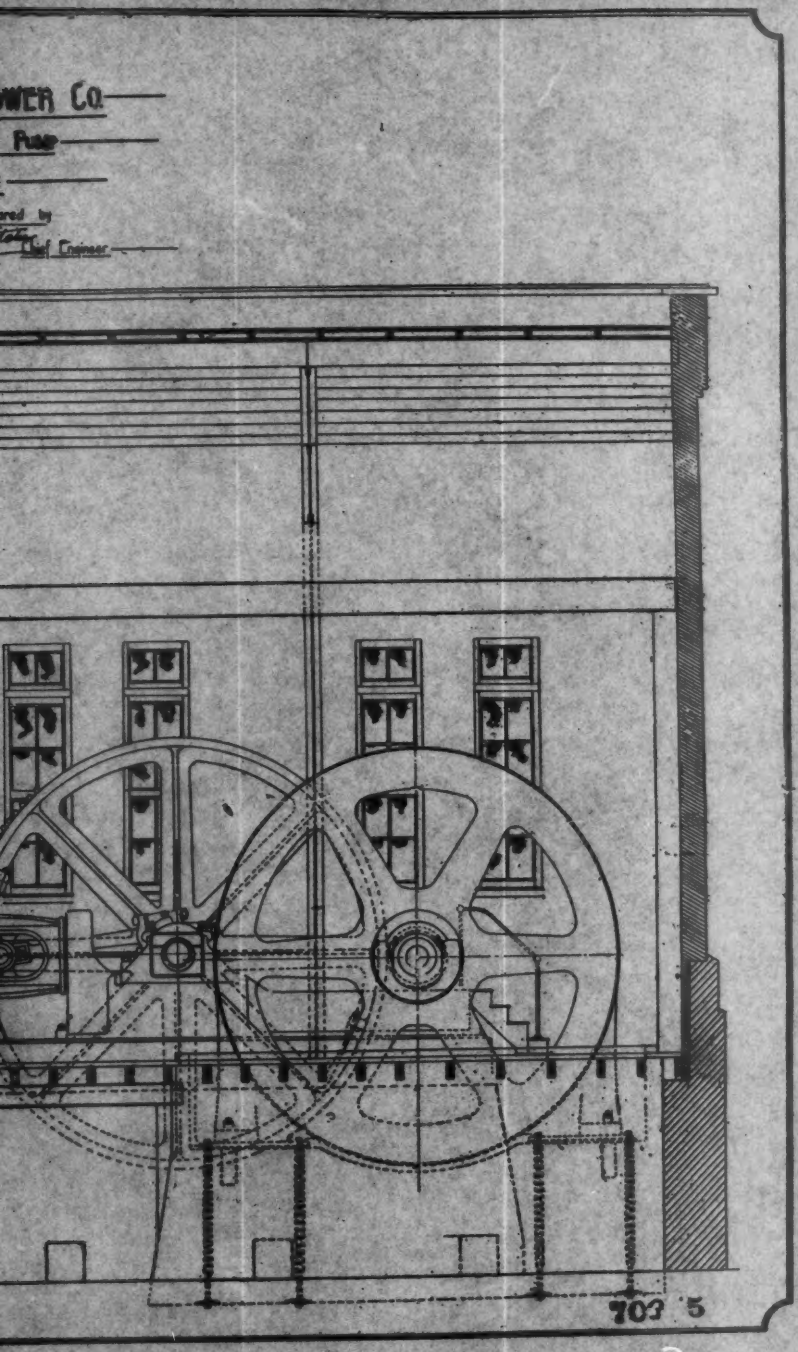
MONTREAL WATER and POWER CO.

SIDE ELEVATION - 18½ x 21 TRIPLEX PUMP

CLARKE AVE. STATION

Montreal Sept. 5, 1903 — Scale 1½" — Prepared by H. W. Peaker, Chief Engineer




WER Co.
Pump
Chief Engineer
703 5

MONTREAL WATER AND POWER CO.
— TEMPORARY DRIVE —
— INSTALLED AT CLARK AVE. PUMP HOUSE —
— WESTMOUNT. —

— TO DRIVE —
— 19½"x21" TRIPLEX PUMP. —

SCALE-½"-1'

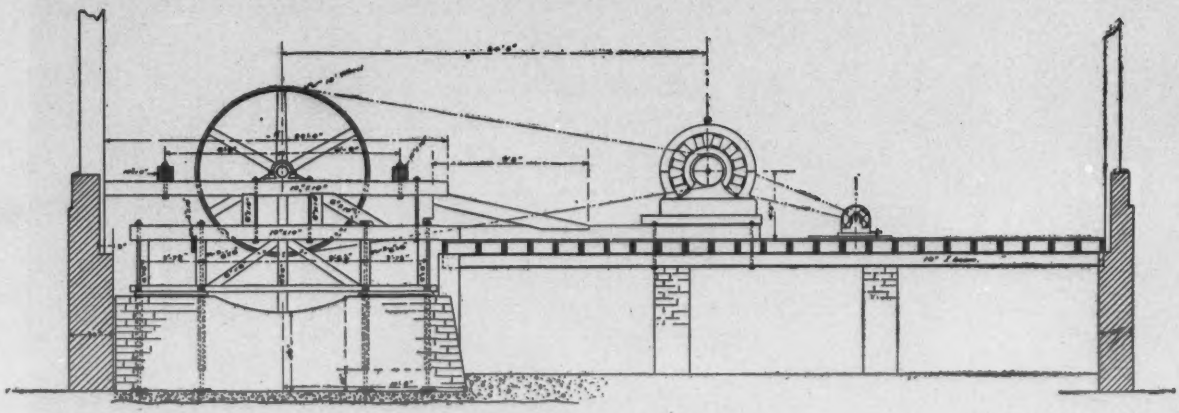


FIG. 4.

nature of things, not shared equally at all times by each gear as with the center crank.

Taking this, together with the unavoidable spring in the crank shaft, it was apparent that there would always be a certain amount of hammering or pounding between these wooden wheels and their respective pinions. The writer was then satisfied that with this arrangement such large mortise wheels could not be made to work.

The builders, however, claimed the trouble to be due to the unsteady support of the pulley end of the pinion shaft, which,

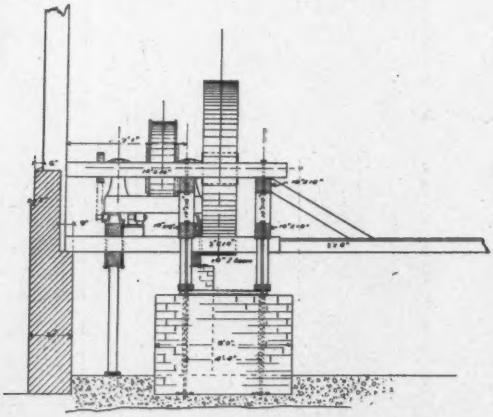
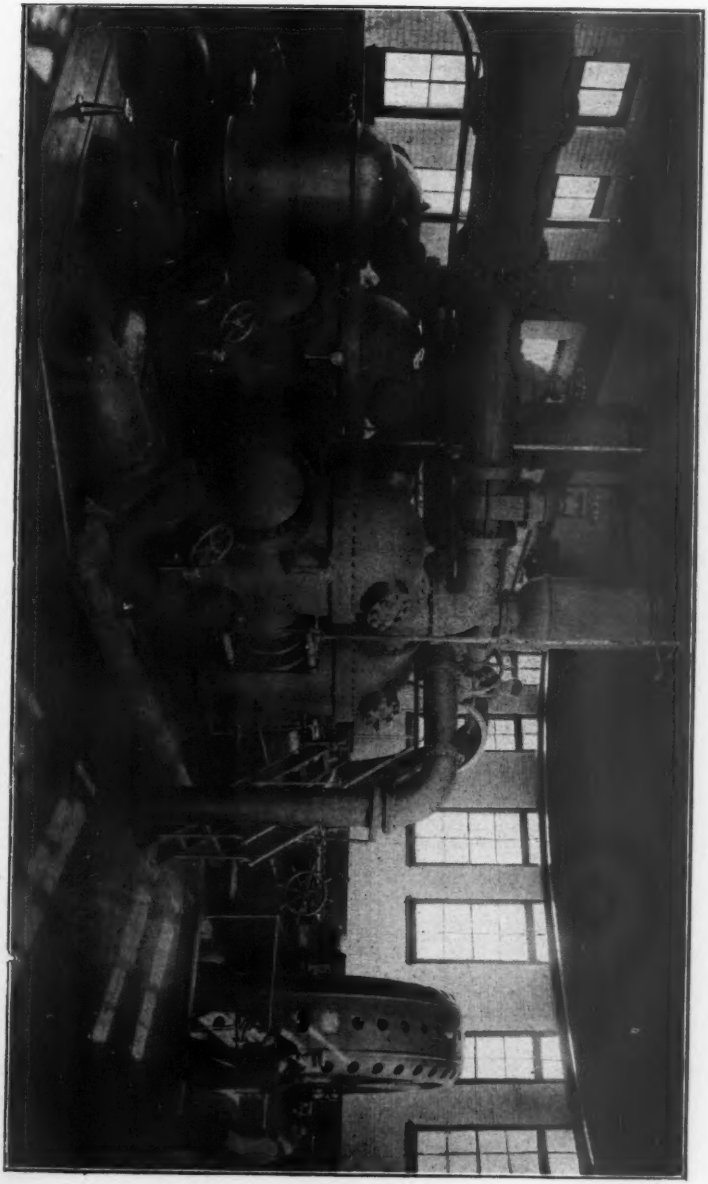


FIG. 5. END ELEVATION OF TEMPORARY DRIVE.

being supported on timbers built up on a foundation about 7 feet below, was not of course the most rigid holding. Considerable oscillatory motion of this end of the jack shaft occurred.

By turning the wooden wheels around, and running with one pair, the pump was kept in operation until the permanent motor arrived. When this was installed it was at once clear, even to the builders, that the gearing arrangement would not work, and it was forthwith abandoned in favor of that now running. This consists of a single pair of gears,— the face being widened to 24 inches,— a machine-cut cast-iron wheel, and, at first, an all rawhide pinion.

PLATE VII.



GENERAL WATER END VIEW OF CLARKE AVENUE ELECTRIC PUMP.

It having been observed that the gears ran better when the working pair was in the pit next the motor, it was thought that a jack shaft of larger diameter would tend to smoothen operation. Furthermore, with a two bearing support for the pinion shaft as would obtain, it was decided to abandon the spherical bearings and substitute stiff bearings of a greater length. Accordingly a 10-inch pinion shaft with bearings of 3.9 diameters (approximately) was installed.

The particulars of this pair of gears are as follows: One machine-cut spur cast-iron gear 24-inch face, 179 involute teeth, 3½-inch circular pitch, pitch diameter 199.42 inches, or 16.61 feet.

The all raw-hide pinion has a 26-inch face, 24 teeth, 26.7-inch pitch diameter (approximately). Reduction ratio 7.45.

This pinion ran for six weeks, and then failed much as the others at the lower station did, but from another cause. The shrinkage was much less, the raw-hide undoubtedly being a superior article, but something happened inside the pinion which prevented it being taken up. It is the writer's opinion that the raw-hide contracted radially and got between the ends of the cast-iron centers carried by the shrouds. However, in spite of plenty of clearance at the ends of the pinion, it was found impossible to compress the hide in the middle so that it was sufficiently tight. The consequence was the load all came on the ends and the teeth got out of shape, causing extreme heating in the pinion. The coefficient of expansion of this substance being high, the ten 1⅞-inch steel bolts holding the raw-hide laterally were broken as quickly as they could be renewed. The raw-hide itself stood the test, and did not break as with the other. The raw-hide was not keyed to the cast-iron center or otherwise secured, except by the bolts passing through from end to end. While this pinion ran it was extremely noiseless at times, but atmospheric changes, particularly the amount of moisture in the air, seemed to have considerable effect on it. An appreciable variation in the running of the gearing was observable, apparently from no other cause than atmospheric changes.

A cast-iron pinion was cut as soon as possible and installed in place of the raw-hide one, pending the arrival of the pinion now running.

The first raw-hide pinion was, of course, the largest ever at-

tempted in face and mass of raw-hide. But in the writer's opinion the very quality to which raw-hide owes its noiselessness—viz., the spring — renders an all raw-hide tooth of such a length impossible for heavy work. The teeth, as above mentioned, spring away from the work in the middle, or point of maximum bending moment, and, the cast-iron teeth of the gear being relatively rigid, too much work comes on the ends, which in consequence show excessive wear in a few days. Unfortunately the writer was unable to hold a *postmortem* on this pinion, without which the above is offered as an explanation of its failure.

The pinion now running is one-third brass; that is, it is cut from a blank having a section of brass in the middle 8 inches wide, with 8 inches of raw-hide on each side. The whole is keyed as well as bolted to the cast-iron centers, which makes a rigid point in the middle of the face of the teeth. This pinion has run since April 9 last, and shows only a slight amount of wear. It is not, however, in point of noise much ahead of the cast-iron pinion. In fact, with its present slight wear it is doubtful whether it runs as smoothly as the iron pinion. The raw-hide people are anxious to try again, using an all raw-hide face having the raw-hide keyed to the centers. I understand they now have one of that type under way.

This pump runs only 20 hours a day, and there is therefore ample opportunity to take up the slack in the raw-hide, etc.

To those visiting this station during the convention it will at once be apparent why every effort should be made to minimize the noise of the pump.

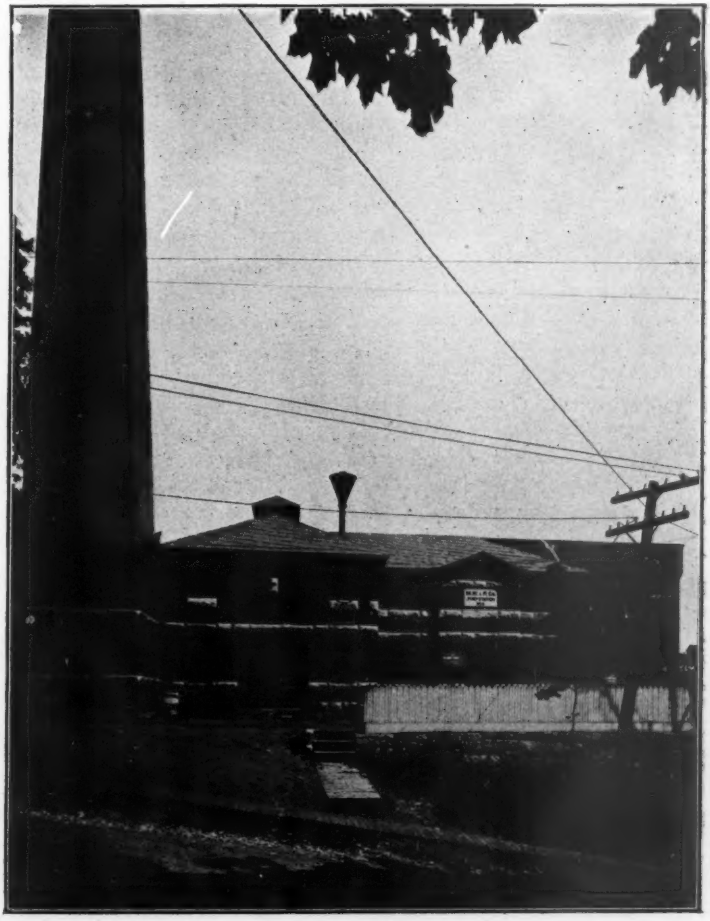
Otherwise than the gearing, this machine has been most satisfactory from the start.

Both the lower station and upper are provided with 10-ton traveling cranes.

DESCRIPTION OF THE CLARKE AVENUE MOTOR.

The motor is a 400-horsepower three-phase 60-cycle 2 200-volt 90-ampères induction machine, having 44 poles and therefore a synchronous speed at 60 cycles of approximately 160 revolutions per minute. In order to keep up the power factor with that number of poles a very large machine with a very small air gap or clearance naturally results. The rotor is 13 feet diam-

PLATE VIII.



CLARKE AVENUE STATION — ELECTRIC STATION IN REAR ON RIGHT.

eter and the stator 6 feet outside diameter. The clearance between rotor and stator is less than 1-16 inch.

The guaranteed power factor at full load is 91½ per cent., full load efficiency 92 per cent., heating limit after 12 hours run 40° C. temperature rise at full load. An overload of 25 per cent. for 2 hours should not show a temperature rise of more than 50° C. at same efficiency. The above is a very liberal rating on this machine, as another 10 degrees would not be out of the way for regular running and 550 horsepower could easily be realized at that limit. The machine passed its test satisfactorily.

It must not be understood that this, with the later city duplicate, are the largest induction motors ever built in point of power. They are, however, it is thought, as large as any in that respect when rated on the same basis. But they are much larger in their diametrical dimensions than anything previously attempted.

This motor is started by first an auto starter in the stator. This is simply a series of transformers so arranged that the line voltage may be applied to the stator windings in gradual steps. This arrangement prevents the sudden rush of current so objectionable to the line and so frequently found in starting smaller induction motors. In the meantime the rotor is an open circuit, which after the full line volts have been applied to the stator is closed gradually through the resistance of a water rheostat. The starting current of this motor is only 30 ampères.

It would, of course, have been preferable from an operating point of view to have had this machine two-phase like that below, but, in order to meet the condition of the electric company supplying the power, three-phase had to be adopted.

This machine is considered a very satisfactory one, remembering that it was the first; the city motor has some slight mechanical improvements.

There has been no trouble like that experienced below in the operation of this motor. A strong short circuit on the line for a few moments makes no trouble in the pumping station.

The starting device is much simpler and less liable to get out of order. Even if it did, the motor could still be started by applying the full line voltage at one step. This would, however, not be agreeable in all probability to the central station people.

EFFICIENCY.

With good steam coal at its present price delivered at that station, the duty of this pump corresponds to 162 000 000 foot-pounds per 100 pounds of coal approximately.

The difference in duty on this basis between the two installations is due, of course, to the higher price of power below and slightly lower cost of coal — the latter on account of the difference in hauling and the former because some 24-hour power is used there.

This motor, as will be seen from the illustration, is absolutely self-contained.

The stator is in two parts divided along a diameter. The rotor is in one piece. The diameter of the shaft through the bearings is 10 inches. The bearings are not self-aligning, which, for a direct-connected machine like this, is considered an advantage.

The approximate weights of the parts are as follows: Stator — Top half, 23 500 pounds; bottom half, 29 500 pounds; rotor, 25 000 pounds.

As will be observed, the peripheral speed of this machine is fairly high, being over 6 500 feet per minute. This, however, in spite of the minute clearance and large diameter of the rotor, causes no anxiety with modern methods of rotor construction.

This equipment would have been most satisfactory from an operating standpoint if it had been thought possible to consider all metal gearing at the outset. Double reduction gearing was ruled out, both on account of its inefficiency, cumbersomeness, and liability to additional disturbance.

THIRD ELECTRIC PUMP.

The third electric pump was installed at the lower station, due to the following considerations:

The additional force and supply mains above mentioned between the lower station and Clarke Avenue reduced the load by more than 30 per cent. on the lower motor. The power contract entitled the company to more than it was possible to use under the new conditions in the same proportion. On this account additional pumping capacity at this station was contemplated in the scheme which included additional force main capacity.

To take full advantage of the capacity of the electric motor already installed, and at the same time utilize all the power available under the old conditions, it was apparent that an additional power pump of one-half the capacity of the original low-level electric pump was possible.

The limits of the building did not admit of a direct-connected pump. Accordingly the additional pump now running was placed " back " and rope-driven from a friction clutch rope pulley carried by an extended shaft of the original 480-horsepower S. K. C. motor (see Fig. 1 and Plates III and IV).

DESCRIPTION OF THE 16½-INCH BY 18-INCH POWER PUMP AT ST. GABRIEL STATION.

The chief consideration here was compactness in proportion to capacity.

A 16½-inch by 18-inch duplex double-acting center-packed pump was adopted, having a capacity of 2 500 000 Imperial gallons. The general water end design is similar to the foregoing pumps.

The pinion shaft was carried back on the cross-head guides to allow of sufficient centers for an efficient rope drive. A feature of this pump, due to the limited space available, was an annular suction air chamber, cast about a section of the 12-inch discharge pipe.

The gearing is essentially a double-reduction arrangement, the ratio between the rope pulleys on the motor and on the jack shaft being 1.36, and the spur pinion and gear of the pump 4.19.

The spur gearing was as follows: One mortise wheel 9 feet 11.04 inches (83.04 inches) pitch diameter, 88 teeth, 4½-inch circular pitch, 16½-inch face. Machine-cut steel pinion, 28.41-inch pitch diameter, 21 teeth. Total reduction ratio between motor and crank shaft, 5.698. Speed of crank shaft, 32 revolutions per minute.

The wooden cogs fared no better than those at Clarke Avenue and failed in much the same way. A loose and badly made key of the pinion shaft pulley might be sufficient to account for the failure.

This gearing was, however, replaced by that now running, which consists of a machine-cut cast-iron gear with 112 involute teeth, 3.2975-inch pitch, 117.56-inch pitch diameter, 17¼-inch face, driven by a steel pinion, 29 teeth, 30.42 pitch diameter. Ratio 3.86.

As far as can be seen this is a satisfactory arrangement. The piston speed of this pump is 96 feet per minute at 32 revolutions per minute..

An additional 5 000 000 Imperial gallon electric pump is now under consideration for this station to meet the growing demand, and at the same time a 12 000 000 Imperial gallon reserve steam plant to be used only in emergency.

THE MOUNTAIN SYSTEM PUMP.

The electric pump used at the Mountain System Station is a small 8 by 10 inch single-acting vertical triplex, driven through double-reduction gearing by a 7½-horsepower 500-volt S. K. C. induction motor. The capacity of this little pump is approximately 100 Imperial gallons per minute.

As mentioned above, this supplies the people living on the Westmount Mountain. There are no special features about this equipment. An exact duplicate can be seen in dozens of cotton mills, etc., throughout the country. They differ from each other only in size and type of drive. No trouble has been experienced with this apparatus.

NEW ELECTRIC PUMP FOR THE CITY OF MONTREAL.

Before closing, mention should be made of an important similar installation now being erected for the city of Montreal at its high-level station.

The pump is, briefly, an 18-inch by 24-inch double-acting horizontal triplex inside plunger packed pump. This is to deliver 5 000 000 Imperial gallons in 24 hours and will be run at a piston speed of about 115 feet per minute.

The general gearing arrangement is similar to that finally adopted at Clarke Avenue, except that a hand-dressed mortise wheel and steel pinion will be used.

Pitch diameter gear 188.44 inches, 148 maple teeth, 4-inch pitch, 20-inch face. Pinion, steel, 31.83 inches pitch diameter, 25 teeth. Ratio 5.9.

As mentioned above, the motor is electrically identical with the Clarke Avenue machine. A change in the method of adjusting the rotor in its housings has been adopted, so that in case of wear at the journals the motor can be easily raised by the wedges

and screws provided for the purpose. The housings or cheeks have been flared outwards and the sole plates widened to give greater stiffness.

TO SUM UP.

The chief problem encountered with large reciprocating electric pumps is in suitably reducing the speed of a comparatively high-velocity prime mover. It is undesirable at present on account of the cost to build an induction motor to run at less than say 150 revolutions per minute with a frequency as high as 60 cycles.

The more modern power installations like that at Shawinigan Falls generate at 30 cycles. This would be very desirable power for reciprocating electric pumps. Unfortunately such a low frequency cannot be obtained in Montreal. The Shawinigan power used in the city is transformed at a local sub-station to 60 cycles so as to coincide with the original Lachine system.

The high-speed turbine pumps, so much used abroad and now being introduced into the United States, may prove, everything considered, more desirable as electrically driven pumps than the reciprocating type.

The principal advantages of large electric pumps in this district are a high comparative duty, which, when the power is on a flat rate, remains absolutely constant. This is a great advantage and eliminates the personal equation of firemen and attendants. They certainly require less attendance than steam pumps of an equal capacity beyond the small sizes. They are clean and generally cause less annoyance to surrounding property holders. They run with less oil and waste. In this district, with the larger sizes, the capital cost of the equipment per horse power is less than a steam plant of equal duty.

A great disadvantage is that not unfrequently the water supply is at the mercy of an outside electric system, which is liable to accident, often causing frequent interruption. In other words, the operation of the pumps is not, from the nature of things, entirely under the control of the water works.

MUNICIPAL USE AND WASTE OF WATER.

DISCUSSION.*

MR. HARVEY D. EATON. I should like to ask Mr. Hill what would be a fair amount for a pupil to consume per day, if he can give an estimate of that, under proper regulations.

MR. WILLIAM L. HILL. I should think four gallons would be plenty.

MR. EATON. What is the usual amount required for a single flushing of a closet?

MR. HILL. That depends on the style of closets. It varies from 3 to 7 gallons. It takes nearly a gallon per day per pupil to flush the closets they have now. The smallest consumption appearing on this table is 2.3 gallons per pupil in a school with 218 pupils. In one school with 868 pupils the consumption was 3 gallons *per capita.*

MR. EATON. Do you think those school buildings are fairly furnished with conveniences so the children are properly accommodated?

MR. HILL. I think they are.

MR. LEONARD METCALF. Is there any apparent reason for the high consumption in any of the schools showing the very high consumption per pupil? That is, are the numbers of pupils very small in those cases?

MR. HILL. Here is one school with 68 pupils, where the consumption is 497 gallons, and here is another school with 426 pupils, where the consumption is 117.

MR. FRANK L. FULLER. I should like to ask Mr. Hill if, after the meters were introduced and the large consumption reported, any large leaks were discovered in the cases where the high figures appeared.

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* This discussion (of paper by John Venner, Chief Inspector, Bureau of Water, Syracuse, N. Y., read at the Montreal Convention by Mr. Wm. R. Hill) was not available for publication with the paper on account of the illness of the reporter. The paper may be found in the September, 1903, issue, p. 268, vol. 17.

MR. HILL. There is no question that there was a good deal of leakage. The meters had only been on three months when this table was made up, and no doubt Mr. Venner later on can give you some very valuable information with regard to leaks in school buildings as well as in other buildings. Here is one school which started with 188 gallons for the month of March, and in the month of May it had got down to 104. Here is one which starts with 44 gallons, and that got down to 28. I read the figures for the last month and not for the first month. The figures for the first month would have been even larger than those I read.

MR. FULLER. Were the meters read every day?

MR. HILL. No, they were not; they were read once a month.

MR. KENNETH ALLEN. What style of water closet was used — whether the individual closet or closets which are flushed in series?

MR. HILL. I do not know; I could not answer that. I had nothing to do with the preparation of this paper. Mr. Venner, the chief inspector, prepared the paper and requested that I should read it. I notice here that in a school of 574 pupils the *per capita* consumption was 6 gallons, in another school with 471 pupils it was 4 gallons, and in another with 353 pupils it was 3.9 gallons; so I think 4 gallons is quite sufficient.

A MEMBER. Do you know whether the buildings are heated with hot air or by steam?

MR. HILL. I do not.

A MEMBER. When you speak of self-closing faucets have you any particular type or make in mind?

MR. HILL. I have not; no.

THE MEMBER. We have had trouble, and would like advice in selecting.

MR. HILL. There are some four or five very good styles, but just what they are is not now fresh in my mind. They are also using a great deal of water in Syracuse for motor purposes for operating fans for ventilating the schools, and that is not included in this table of consumption at all.

MR. FULLER. That is unmetered water?

MR. HILL. Yes, that for the motors is unmetered, but Mr. Venner is placing meters on them, so he will be able later to give you the information in regard to that. Three and three-fifths

per cent. of our entire consumption going to 34 schools certainly shows an enormous wastage of water.

MR. F. L. FULLER. It seems to me that this paper which Mr. Hill has read gives us another example of the foolish way in which water is sold, not perhaps so much now as formerly, but it seems absurd that a commodity that has any value at all should be sold or distributed in the way that water is, in many towns. My own town, Wellesley, perhaps furnishes a good illustration of this point. For a number of years after the works were built, our water was sold by the faucet, and the consumption increased very rapidly, doubling in a year or two. When our consumption reached about 93 000 000 gallons a year, if I remember correctly, we began to put in meters, and although the number of takers continued to increase, the consumption began to decrease, and continued to decrease somewhat in proportion as the use of meters increased, and for a number of years, perhaps six or eight, our consumption has been less than the maximum it had reached before meters were introduced. We now use, I should say, 80 000 000 gallons a year, whereas ten or twelve years ago we were using 93 000 000 gallons, and probably we have twice as many consumers now as then.

I read the meter in my own house every morning, or try to, just for the sake of seeing how the consumption varies, and it is quite interesting to keep that record. We have five in the family generally, and the consumption is perhaps 5 or 6 cubic feet for the minimum, while on washing days it will run up to from 10 to 15 cubic feet, which is a good deal less than many of the figures which Mr. Hill has read. Of course the use of water in a private dwelling house, the legitimate use of it, is a great deal larger than it would be in a school building; that is, the water used for washing clothes and for washing dishes and such uses as that would not pertain to a school building. The amount of water used in the water closets might be practically the same, but I should suppose that would be less *per capita* in a school building than in a private house. But this all points, certainly, to the reasonableness of the use of meters. When a meter can be bought for from $8 to $10 which will register all the water which an ordinary house will use, and which will last 12 or 15 years, — I don't know just what the life of a meter is, — it seems as though it were a wise invest-

ment for a town or a city to make. In Wellesley the town owns the meters and the people have no expense on account of them, except to keep them from freezing.

MR. EATON. I should like to ask Mr. Hill if such a condition of wastage of water as he has shown to exist in Syracuse does not indicate a pretty serious impairment of the efficiency of the fire service; in other words, if it does not reduce the pressure.

MR. HILL. That would be true where there was a system of small-sized pipes, like some systems I know of, for example, at Waterville, Me., where they have 31 miles of pipe and 12 of it is less than 4 inches in diameter. I think a large consumption or waste of water there would seriously interfere with the fire service. In fact, on these 12 miles of main they have no fire protection whatever, in my opinion. In a city where they have large mains the wastage in school buildings would have a very small effect, but the general wastage might have a very serious effect.

MR. EATON. I meant if such conditions prevailed in all the services, not only in the schools.

MR. HILL. Oh, yes, I should think so; yes, indeed.

MR. F. W. DEAN. In regard to the matter of fire protection with small pipes, I was somewhat instrumental in having the Metropolitan water introduced into the town of Lexington, where I live. They had a well system there, and the water was pumped by a small pump into a standpipe, and there was considerable head. There was a good deal of feeling in the town against introducing the Metropolitan system, because it was thought by many persons that the Metropolitan Water Board was anxious to get all the towns possible in, in order to help pay the bills for the establishment and maintenance of the system, though of course anything that Lexington could have contributed in that direction would have been but a drop in the bucket. It is rather amusing that one of the strenuous opponents to the Metropolitan system had his house located about three thousand feet from the main line, and a 4-inch pipe led in that direction. His house caught fire, the first house which caught fire after this agitation occurred, and it was entirely consumed, for there was not force enough to throw the water upon the roof.

HISTORY AND DESCRIPTION OF THE MONTREAL WATER WORKS.

DISCUSSION.*

MR. J. C. HAMMOND, JR. I would like to ask Mr. Janin if they have an overflow to their high-level reservoir, or if they have to watch the gages.

MR. JANIN. Of course we have an overflow, but the gages are watched. We pump only in the daytime. We have a reservoir capacity of about 1 750 000 Imperial gallons, and the consumption is about 2 200 000. The present pump is worked twelve or fourteen hours a day. The reservoir is left full every night, and the next morning the water level is found to be down six or eight feet when the pumping is resumed at six o'clock. The pumping is maintained all day, and along towards four or five in the afternoon we find we get near the overflow, and then the pump is run more slowly until six or seven o'clock, at which time the reservoir is left full.

MR. FRED BROOKS. Will you please explain what is meant by "frasil"?

MR. T. W. LESAGE.† Frasil is the name given in this country to ice which forms in swift running water in cold weather.

MR. FRANK L. FULLER. What we call anchor ice?

MR. LESAGE. No; there is considerable difference in the formation of the two kinds of ice. It is not what is called anchor ice, which generally forms in calm water. Frasil or slush ice is formed in very rapidly running water. The water in our rapids is running at the rate of six miles an hour or more, and this frasil ice forms in very cold weather on the surface of this swift running water, and then slowly sinks, or partly sinks, and attaches itself like

*This discussion (of paper by George Janin, C.E., Superintendent, Montreal Water Works) was not available for publication with the paper on account of the illness of the reporter. For the paper, see page 272, vol. 17, September, 1903.

†Assistant Superintendent Montreal Water Works.

anchor ice to the bottom, or to any other ice that happens to be there, and it impedes very much the flow of our aqueduct, as it lodges in a spongy, slushy mass under the surface ice.

In the fall of the year, before our settling basin in the head race freezes over, late in November or early in December, if there are two or three days when the temperature is less than ten above zero, it generally happens that the gratings at the entrance of the wheel pits are completely clogged by this frasil ice. It makes a nearly watertight joint, so that there is hardly a drop of water goes into the wheel pits through the gratings. That state of things continues for a night or so, or until the surface of the basin is covered with ice, and then we are free from the trouble to our wheels for the remainder of the winter. During most of the winter time, however, the frasil will flow with the current into the entrance of our aqueduct from the Lachine Rapids, and it thus interferes with the flow of the water.

It has certain distinguishing features from anchor ice, although just at the moment I cannot explain them. We have had considerable discussion on the subject, and there are certain theories about the formation of this ice, but of course I have only spoken of the practical side or of the troubles it occasions. The name of it here is frasil, or slush ice; the old river men have always called it frasil.

MR. LEONARD METCALF. I would like to ask whether you have had any trouble with electrolysis on your pipe system, from the trolley lines.

MR. LESAGE. We have had a little trouble with electrolysis, but not to any great extent. We have had it only in the near neighborhood of our street railway power house, on one or two streets. Our trolley system is pretty well safeguarded, I believe with return conductor wires, and probably that is one reason why we have not had more interference on that score.

MR. METCALF. Is the trouble on the service pipes or on the mains?

MR. LESAGE. We have it especially on the mains. The power house is situated about 300 yards from the canal, and they take water therefrom for condensing purposes through two 24-inch mains which run very close to one of our 6-inch water pipes, and we have had more trouble with that pipe than with any other.

The pipes running into the power house seem to act as storage batteries, I suppose, and we get the full benefit of it on this 6-inch pipe. Aside from that we haven't had much difficulty. Our service pipes are very little affected, except those in close proximity to the power house.

MR. KENNETH ALLEN. What hydrants do you use here?

MR. LESAGE. They are an adaptation of the Matthews style of hydrant; we make them ourselves, and they have a rather heavy outside casing for frost protection purposes.

MR. HAMMOND. At what depths are your mains?

MR. LESAGE. Generally they are six feet; the smaller pipes, less than 8-inch diameter, have six feet on top.

MR. F. W. DEAN. I presume it states somewhere in the paper what the source of the electric power is to be for the new high-service pump, but I don't remember it, and therefore I will ask the question as being the easiest way to find out.

MR. LESAGE. No; it is not stated in the paper. The contract was made originally with the Lachine Rapids Hydraulic and Land Co., but since that time all the electric light and power companies in Montreal have been merged into one, and all are under one management at the present time. We have a five-years' contract with them to supply the power.

MR. DEAN. What horsepower will be required?

MR. LESAGE. From 385 to 400.

MR. DEAN. I suppose that is with an alternating current?

MR. LESAGE. Yes.

MR. DEAN. What voltage is to be used?

MR. LESAGE. Twenty-two hundred volts. I believe you are going to have a paper on this subject later on by Mr. Pitcher, which I think will give all this information.

A MEMBER. What do you have to pay?

MR. LESAGE. Owing to competition at the time we got advantageous rates. As our plant is to run at present we expect to get along with twelve hours' pumping, and we figured that if we ran at night we could get a much cheaper rate than for day running. The prices offered were for twelve hours' pumping for the required amount of horsepower, 385 to 400, at a flat rate of $26 per horsepower per year for day running, or $20 for night running, and we took the night running rate, that is, from 10

P. M. to 10 A. M. It is a question, however, whether we will be allowed to run this machinery at night. The pumping station is in a strictly residential portion of the city, and it may be that the residents will not like the night running, especially in the summer time.

MR. METCALF. Can you tell us what you have to pay here for coal?

MR. LESAGE. Up to last year, or the recent rise, a year or a year and a half ago, we used to get coal for $3.25 to $3.50, but now I believe we are paying somewhat over $4 for Cape Breton or Nova Scotia coal, which comes by water. Of course imported by rail in the winter time it is more expensive.

MR. METCALF. You mean for a long ton, of course?

MR. LESAGE. No, a short ton, 2 000 pounds.

MR. ALLEN. Do you know how your coal compares with the Pennsylvania coal?

MR. LESAGE. There are three or four varieties of coal which we get, and I could not say about any particular kind. Some of it is better than others. There have been comparisons made between our coal and the Southern coal, but I don't know that there have been any recent comparisons, and I cannot state anything definite with regard to the coal that we get at present.

MR. FULLER. I suppose that your works are more than self-supporting?

MR. LESAGE. That opens up a pretty large question in Montreal. Our water rates are at present the subject of considerable discussion. We have what we call the water rate here, a general municipal tax, which is not meant to be the price of water, but is generally applied for street cleaning and lighting, fire protection, police tax, and everything else. This water rate is based on percentage of the rental. It is 7½ per cent. of the assessed rental. Take a property on a good residential street, for example; it may be assessed for rental of $800 or $1 000 yearly, and there will be perhaps only three or four people in the house, and the rate will be 7½ per cent. on that amount, or $60 or $70 yearly water rate; while down in the poorer portion of the city, where the house will only be assessed at say $120 a year, and there will be perhaps eight or ten persons in it, and the women of the house may take in washing and otherwise use perhaps ten times as

much water as is used in the uptown house. You see can the difference in the water rates that they pay. It weighs heavily on the rich man and lets the poor man off. The city, however, has been accused of making too large a profit on its water, which is more or less true, but of course the management of the water department does not get the amount of money which is collected.

MR. FULLER. Do you use any meters at all?

MR. LESAGE. The number of meters is somewhat limited, about 1 100 of all sizes. We use them just for large industrial establishments, factories and such like, so as to prevent waste.

MR. HAMMOND. What do you use for house service pipe?

MR. LESAGE. Lead pipe altogether, except in 2-inch we use galvanized iron.

MR. P. KIERAN. What is the quality of the water, bacterially and chemically?

MR. LESAGE. It varies a good deal. I don't know that we have had any very recent analyses made, but our water compares very favorably with most waters. In the spring of the year when the river is running pretty full the water is cloudy and turbid. Although we take our supply from the St. Lawrence River, the water we get is mostly Ottawa River water. As you are aware, Montreal is on an island, and at the upper extremity is the confluence of the two rivers, the Ottawa and the St. Lawrence; the Ottawa River strikes the shore of the island, and thus we generally get Ottawa River water at the intake of our aqueduct. It is a little less hard than the St. Lawrence River water, and a little more highly colored with vegetable matter. There are certain times in the winter when a short stretch of water at the head of the island becomes obstructed by ice, and probably for a month or six weeks all the Ottawa River water comes down at the back of the island, and we get then St. Lawrence River water at the intake of our aqueduct.

COVERING THE NATICK, MASS., RESERVOIR WITH A CONCRETE ROOF.

BY FRANK L. FULLER, CIVIL ENGINEER, BOSTON, MASS.

[*Read September 10, 1903.*]

The water supply for the town of Natick was introduced in 1874, the late M. M. Tidd being engineer. The source was Dug Pond, a tributary of Lake Cochituate, situated about one mile southwesterly from the business center of the town. The water was pumped into an open reservoir on Broad's Hill in the easterly part of the town.

The reservoir does not appear to have been originally well built, for in 1876 the bank on the west side gave way, and it was entirely emptied. The break was repaired by the town at an expense of $645.90.

In regard to the paving on the inside slopes, the superintendent says in his report for 1878: "The slopes inside are a continual source of trouble, and will be till they are either paved with granite blocks, with granite chips underneath to prevent wash and growth of weeds and grass, or that the small stones which are there should be laid in cement grout to make them water-tight, thus preventing the water from becoming roily at every high wind." In his report for the year 1883 the superintendent says: "There is one source of trouble which should be remedied, that is, the growth of weeds on the bottom, — which is very filthy, — which has become rooted so that it grows very heavily and quickly when the water is warm, and causes it to taste. This can be overcome by cementing the bottom, which would save the expense in a few years, as it takes about three days to clean it, with a number of men, which could be done in as many hours if the above suggestion were carried out."

Nothing was done in this connection until 1902, during which year the work described in this paper was completed.

In 1886 the sum of $71.66 was expended in cleaning the reservoir.

At the annual meeting in 1890 the town authorized the water commissioners to "repair and enlarge the reservoir." This was done by day labor under direction of the superintendent, the contract for paving stone, broken stone, and cement being awarded to the lowest bidder. The old slope paving was removed to within about 5 feet of the bottom, and used in building a core wall through the reservoir embankment. The new paving consisted of granite blocks 1 foot wide, about 7 inches in depth, and averaging about 18 inches in length, laid on 5 inches of broken stone placed upon the old bank. The paving blocks were laid in cement mortar of good quality, as indicated by the difficulty in removing the stone at the points where piers of the outer row were to be built. Only on the southerly side, at about the elevation of high water, where the effect of waves and ice was the greatest, were any open or poor joints found. No settlements, except some very slight ones along the line mentioned, were discovered. The work is a credit to the late Mr. J. W. Morse, at that time superintendent of the Natick Water Works and for some years a member of this Association, and to the workmen under him. (See Plate I, Fig. 1.)

At this time the embankment was raised 2 feet, and high water level 3½ feet, in order to furnish a better supply at the residence of Mr. H. S. Hunnewell, situated near the Wellesley line.

As originally built, the reservoir was 17 feet deep, high water being considered as 14 feet above the bottom, or 3 feet below the top of the embankment. After the height of the embankment was increased the reservoir was 19 feet deep, and high water was fixed at 17½ feet above the bottom, or 1½ feet below the top of the embankment.

The original paving was of small stones, except at the bottom, where those forming the footing course were of good size. The portion within five feet of the bottom, which was allowed to remain, was pointed with Rosendale cement, and presents a fairly smooth and even appearance. The core wall was built by excavating a trench near the center of the embankment and filling it with the stone which formed a portion of the original slope paving, laid in mortar probably composed of Rosendale cement and sand. The wall probably extends somewhat below the original surface of the ground. On a plan made by Mr. Tidd, dated February,

FIG. 1. — RESERVOIR BEFORE CONSTRUCTION OF ROOF WAS BEGUN.

FIG. 2. — REMOVING FORMS FOR PIERS.

1890, a section at a point, probably on the westerly side, and near the southwest corner of the reservoir, shows the wall as 1.5 feet thick at the top and 2.5 at the bottom and 8.0 feet high. Its top is shown as 1.5 feet below the new top of the reservoir bank, and it extends 1.5 feet below the old surface at that point.

Whether the wall was built according to this plan, the writer has no means of knowing. At the point where a cut was made through the embankment for the entrance of the new 18-inch force main, the bottom of the core wall is about 3.5 feet above the bottom of the reservoir, and about 4.8 feet thick. The new force main is 15.17 feet north of the old 12-inch main, and the thickness and depth of the core wall at the point mentioned may be due to its proximity to the old force main.

Until the laying of the new force main the reservoir had no overflow or waste pipe, and on one occasion the water, due to excessive pumping, overflowed the bank. No especial damage was done, however. The engineer had only his pressure gage to rely on, which is not sufficient, especially where there is not an overflow pipe of good capacity.

The new granite paving extended entirely to the top of the embankment, and the inside edge of the reservoir at the top is practically rectangular, with rounded corners of about 38.5 feet radius. (See Fig. 1.)

The average inside dimensions of the reservoir at the top are 217.0 feet from east to west, and 212.0 feet from north to south. The corresponding figures for the bottom are 159.8 and 154.3 feet.

The area within the top of the slope paving, which is the area of the top of the concrete roof, is 44 730 square feet, and the area at the bottom is 24 570 square feet.

The capacity of the reservoir before covering, with high water 17.22 feet above the bottom, was 4 340 000 gallons. With the same high water, it is now 4 280 000 gallons

A NEW WATER SUPPLY.

For several years the water supplied from Dug Pond had been of poor quality and insufficient in quantity. The water often had a disagreeable taste or odor, especially in hot weather and sometimes in winter.

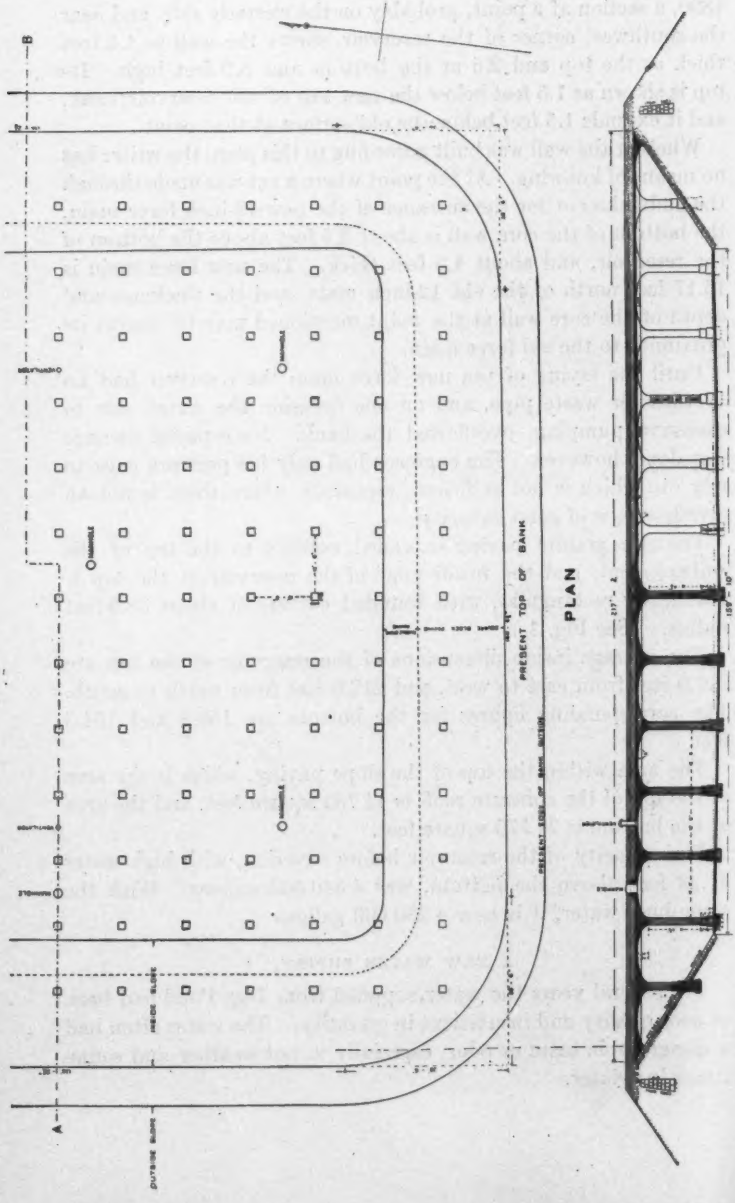

FIG. 1. — PLAN AND SECTION OF CONCRETE ROOF OF NATICK RESERVOIR.

SECTION ON LINE A-B

FIG. 1. — PLAN AND SECTION OF CONCRETE ROOF OF NATICK RESERVOIR.

PLATE II.

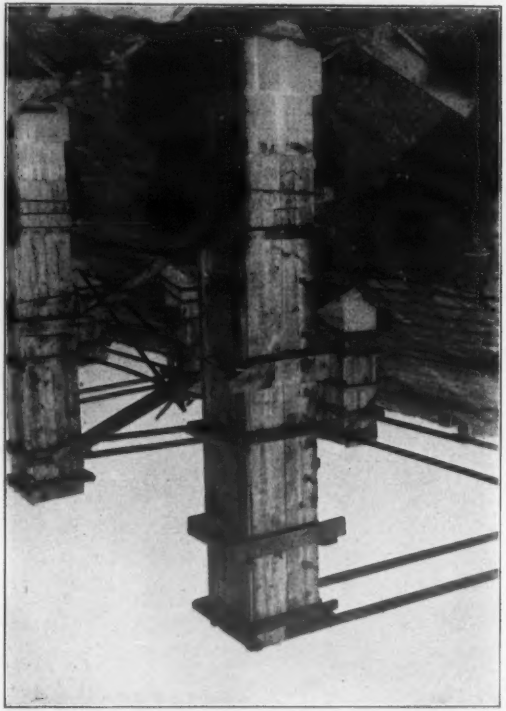

FIG. 1. — FORMS FOR UPPER SECTION OF PIERS.

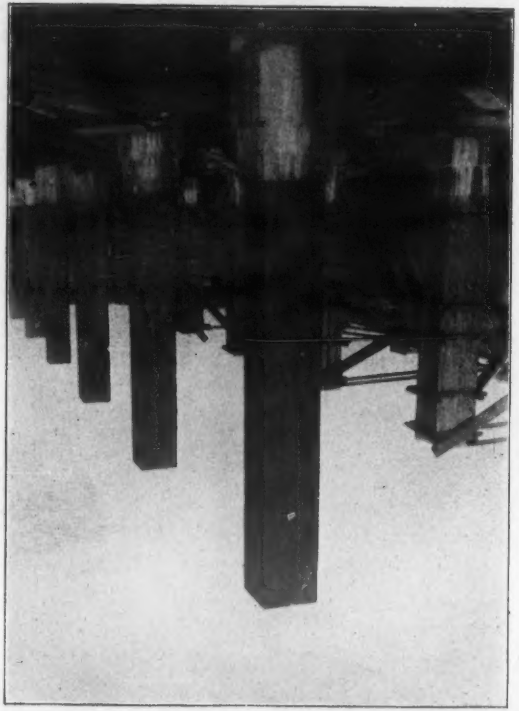

FIG. 2. — PIERS.

The pumping station was situated upon an arm of the pond, into which a brook * which drains a part of the thickly settled portion of the town empties. The water of this brook was badly polluted, especially before the construction of the sewerage system in 1896.

The town had for some time been advised by the State Board of Health to secure a new supply, and, in the spring of 1902, appropriated $150 000 to be expended in obtaining such a supply, building a new pumping station, installing a new high-duty pumping engine, laying a new 18-inch cast-iron force main from the new pumping station to the reservoir, and covering a part or the whole of the existing distributing reservoir.

Tests made by Mr. Percy M. Blake, C.E., in 1899 or 1900, established the fact that a supply of ground water, probably amply sufficient for the needs of the town, could be obtained upon land owned by the town, situated on the borders of Lake Cochituate on the southerly side of Worcester Street.

The adoption of this supply, and the now almost universally recognized necessity of storing ground water in covered reservoirs, made the addition of a roof, or covering, to the existing open reservoir almost imperative. Late in the spring of 1902 surveys were made, plans and specifications prepared, and proposals asked for the various items of work to be done, except the pipe laying, which was done by the day by townspeople under direction of Mr. George W. Travis, Superintendent of the Natick Water Works and member of this Association.

CONSIDERATION OF METHODS TO BE ADOPTED.

Considerable time was spent in studying the open reservoir and its condition and the best way of securing the desired result. It was at first thought that it might be sufficient and less expensive to cover only one-half of the reservoir, but this would require the construction of a heavy cross wall, sufficient to resist the pressure of a depth of about eighteen feet of water on one side only. The expense of this wall would pay a large part of the cost of covering the other half of the reservoir.

The question also arose whether the slope paving should not

* This brook was originally a branch of Pegan Brook, but had been diverted into Dug Pond before the city of Boston acquired Lake Cochituate and Dug Pond in 1847.

be removed, a portion of the inner slope excavated, and a heavy masonry wall built on the four sides, from which the covering arches should spring.

Approximate computations and a careful consideration of the subject led to the adoption of the method of covering about to be described.

On careful examination the slope paving was found to be of such excellent quality, and the banks so hard and compact, that it was considered safe to allow the concrete arches to abut directly upon the slope paving. This would save a large expense in removing the slope paving and excavating part of the bank and building expensive retaining walls, which seemed unnecessary.

The covering of the entire reservoir would give the town the advantage of a 4 000 000 instead of a 2 000 000-gallon reservoir. Moreover, the appearance of the reservoir entirely covered would be much better than it would with one-half covered and one-half open, even if the second half were filled with water.

It was, therefore, decided to cover the entire reservoir, and the completed work fully justifies the course taken.

DESIGN OF PIERS AND ROOF.

From the beginning it was assumed that a large number of piers would be required. Whether a system of lintel arches between piers and parallel segmental circular covering arches, or groined elliptical arches, should be used, was considered. The less cost of concrete, as compared with brickwork, and the possibility of its erection by unskilled labor, made its use desirable wherever possible. Groined elliptical arched vaulting can easily be constructed of concrete, and is economical in material. In the case of lintel arches and segmental circular covering arches, the lintel arches and the filling over them would be almost of necessity of brick. The centering for the groined arch vaulting is probably more expensive than that required for the circular covering arches. Taking all things into consideration, however, the groined elliptical arch method of covering was adopted. The specifications were so drawn that brick or concrete piers could be used.

The price bid by Mr. F. A. Snow, whose proposal was the lowest, was $9.50 per cubic yard for concrete and $14.00 for brick

FIG. 1. — REMOVING FORMS FOR PIERS.

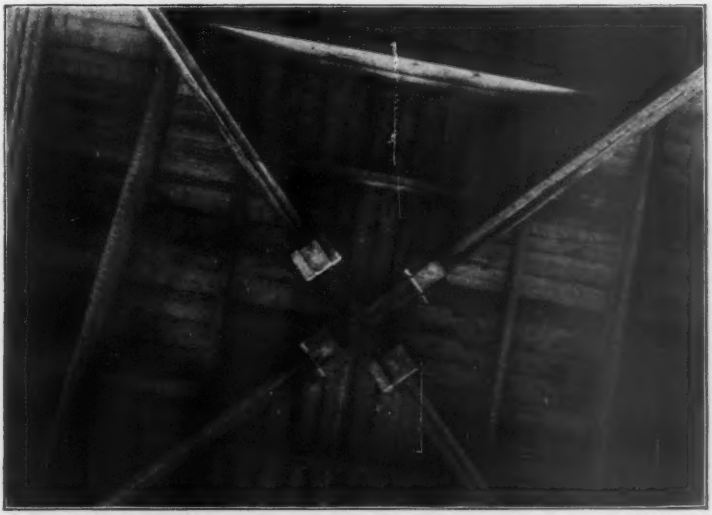

FIG. 2. — UNDER SIDE OF ROOF CENTERING, SHOWING CLAMPS CONNECTING FOUR QUARTER SECTIONS.

piers. Concrete was, therefore, adopted, the saving to the town thereby being $1 828 80.

Thirteen rows of piers, with 13 in a row, or 169 in all, spaced 15 feet 2 inches on centers, were adopted for supporting the roof. The reservoir, as before mentioned, was not exactly rectangular, but the piers were arranged so that the four lines bounding the outside of the system of piers formed an exact square, 183 feet 8 inches on each side.

In this rectangular system of piers the number of rows was such as to make it necessary that only the outside rows of piers should be built into the inner slopes of the reservoir. (See Fig. 1.)

Ribs of different lengths were required in the centering between the outer rows of piers and the slope paving, according to the slightly varying dimensions of the reservoir. (See Plate IV, Figs. 1 and 2.)

The piers and their foundations, located within the foot of the slope, have the following dimensions: Pier foundations are 3 feet by 3 feet by 1 foot 6 inches deep, the top of the foundation being at the level of the under side of the 4 inches of concrete covering the bottom. The first section above the foundation is 2 feet 4 inches by 2 feet 4 inches, with a height varying from 1 foot 6 inches to 2 feet 6 inches. The tops of these sections are all at the same elevation, which is 1 foot 6 inches above the bottom of the reservoir at the outer edge. As the reservoir bottom has a uniform slope from the outer edge to the center, where the bottom is 1 foot lower, it will be seen that the length of this section varies according to its location.

The second section above the foundation is 2 feet by 2 feet by 1 foot 6 inches.

The third, or upper section, is 1 foot 8 inches by 1 foot 8 inches by 12 feet 5⅝ inches.

In the four outer rows of piers the foundations were carried below the original surface of the ground, and were generally of larger horizontal and vertical dimensions. The length of the other sections varied according to circumstances.

The elliptical arches used in the design of the roof have a span of 13 feet 6 inches and a rise of 2 feet 9 inches. The thickness of the concrete roof at the crown is 6 inches and over the piers 3 feet 3 inches.

The top of the concrete roof is level with the average top of the slope paving at its upper inside edge, and extends to it.

CONSTRUCTION.

Concrete alone was used in foundations, piers, and roof. The specifications provided that the concrete used should be of either the Alpha, Atlas, Iron Clad, Lehigh, Vulcanite, or Brooks-Shoobridge brand.

Of these the following amounts were used: Atlas, 2 200 barrels; Brooks-Shoobridge, 200 barrels; also 200 barrels of Alsen's American Portland, making 2 600 barrels in all.

The concrete was to be composed of 1 part of cement, by measure, 2½ parts of sand, and 4½ parts of broken stone or screened gravel. The sand and stone were to be of acceptable quality. Mr. Snow decided to use screened gravel. This and the sand, which were from the same pit, were of excellent quality, the sand being coarse, clean, and sharp. The concrete was mixed by hand and quite wet. As carried in a wheelbarrow there was usually a thin layer of water over it. But little difficulty was had in filling all voids, and on removing the centers but little porous or defective work was found, due, it is believed, in a considerable degree, to the wet condition of the concrete, which could be easily rammed into place.

Work was begun at the southeast corner and progressed from east to west, the northwest corner being the finishing point. The mixing platform, until the piers were finished, was at the top of the bank at the southwest corner.

Excavations of the proper size were made in the bottom for the pier foundations and grade marked for the top of the concrete. The wet concrete, with the aid of a little tamping or cutting with a shovel, entirely filled the hole, and, what is of considerable importance, the top, when set, was perfectly level and smooth, ready for the forms for the next section.

For foundations of this character, good concrete has much to recommend it.

The forms, or bottomless boxes, as they might be called, for the 2 foot 4 inch by 2 foot 4 inch sections, were placed upon the concrete foundations and set in line one way, by a transit instrument. The box was placed as nearly in position as possible on the other line by the eye. Two stakes were then driven into the ground on

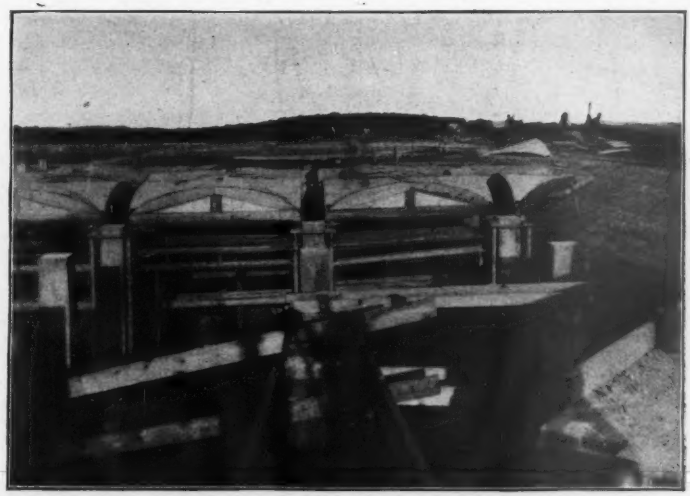

FIG. 1. — CENTERING AND BRACING.

FIG. 2. — CENTERING AND CONCRETE AT SLOPE PAVING.

each side of the box, so that pieces of 2-inch by 1-inch furring would rest on the top of the stakes and against the sides of the boxes. The furring being nailed to the tops of the stakes acted as guides, between which the boxes could slide a short distance either way. The middle box was then centered by setting the instrument over the center line of the reservoir, at right angles to the line first given. Then by means of a steel tape attached to the middle box at a point on the center line of the reservoir, marked upon the side of the box, the remaining boxes were pushed or driven in the proper direction, between the guides, till each was at the correct distance from the center. Two additional pieces of furring, one on either side of the box, were then laid upon the guides and at right angles to them and pressed close to the box. They were then nailed to the guides, securing the box or form in position.

Grade for the top of the section, which was the same elevation at all the piers, was then marked on the inside of the boxes, and they were ready for filling with concrete.

The two center lines, or axes of the reservoir, had been carefully established, both on the bottom and on the top of the reservoir bank. From these the center line of each row of piers had been accurately fixed by stakes in the bank at the top. By setting an instrument over a stake and sighting to the corresponding one on the opposite side of the reservoir, line for that particular row of piers could be easily given with certainty that it was correct. Great care, of course, was necessary with the tape measurements that the piers might be properly spaced upon the line given by the transit instrument.

The forms for the 2 foot by 2 foot by 1 foot 6 inch sections were set in the same manner, generally before the forms for the section below had been removed, as the upper form could be secured in place by cleats nailed to the lower. In a day or two, or when needed, the lower form could be removed, leaving the upper one to be removed at the proper time.

The forms for the upper, or 1 foot 8 inch by 1 foot 8 inch by 12 foot 5⅝ inch section of the piers, were raised into place upon the top of the 2 foot by 2 foot section, by resting one end upon the top of the completed section and the other on a cement barrel placed opposite the pier. By means of a rope attached to the

upper end, two or three men upon a run or platform at the level of the top of the finished pier, with the help of a few men below, could easily pull it into a vertical position.

The bottom of the form was then easily adjusted, by the eye, upon the top of the 2 foot by 2 foot section, as the outside of the upper form was of the same dimensions as the top of the concrete section upon which it was to rest. The bottom of the form was then secured in place, generally by means of 2 inch by 3 inch pieces, nailed or spiked on either side, from form to form, extending from the east to the west slope of the reservoir.

The bracing at right angles to the line of piers being built was generally by two pieces of 2 inch by 3 inch spruce, spiked to the form directly south, or if that form had been removed, by bracing from the lower pier sections on either side.

The tops were then put in line one way by the instrument and spaced by tape measurement nearly in the same way as in the case of the 2 foot 4 inch by 2 foot 4 inch sections already described.

The tops were secured in place one way by 2 inch by 3 inch pieces spiked to the form to the south, or, if that had been taken down, by a long 2-inch plank on either side, abutting against the lower section of the pier to the north and that to the south. The bracing in an east and west direction was the same as at the bottom.

A timber platform or run at the level of the top of the piers, supported on sill pieces resting on the bottom, furnished the means of reaching the top of the form from the mixing platform with wheelbarrows.

The concrete was dumped from the top into the long forms. By putting the 20-inch pieces into the front of the form at the bottom only as fast as it was filled, as explained under "Centering," an opportunity was had to ram the concrete and also to keep stones away from the sides of the forms by means of a spade. This precaution prevents the stone from showing on the surface of the pier and gives it a smoother and more finished appearance.

The run, or longitudinal platform, extending in an easterly and westerly direction, could be moved northerly with bars by men stationed along the length of it, in the same way that a railroad track is often moved laterally. After one row of piers had been built by means of it, it was moved northerly one space, or about fifteen feet, and an additional row built.

The minimum time allowed before the forms for piers were removed was about four days. Generally they were allowed to stand longer.

The concrete for the roof was usually put on in sections 30 feet 4 inches wide, the joint being along the crown of the arch. A 6 inch by 6 inch spruce timber was laid along this line, and the concrete left flush with its upper surface.

The minimum time allowed for the removal of roof centers, after the concrete had been put on, was ten days. In some instances the centers remained in place two weeks or longer, or until they were needed for another portion of roof, or in other cases until it was desirable to remove the supports for the purpose of concreting the bottom.

A small amount of excavation was necessary on the bottom, and the material removed was thrown, by successive lifts, to the roof and spread over the concrete, protecting it from too rapid drying. In addition to this an amount sufficient to make in all a thickness of about one foot was taken from a borrow pit on the north side of the reservoir.

It was intended to cover the concrete roof to a depth of two feet, but before this could be done the borrow pit became so frozen that only about one foot, as before mentioned, could be obtained, and the remainder was not put on till the following spring.

A few fine cracks appeared on the upper surface of the concrete, generally over the piers. It was thought that they were produced by a slight yielding of the centers at some point between the piers. When it is remembered that the concrete supported by each pier weighs 15 tons, and that before it is set its weight is entirely on the centering, it is not surprising that a very slight settlement, sufficient to form cracks around the unyielding pier, should take place. In no case were they thicker at the surface than a penknife blade, and appeared thinner below. Sometimes liquid grout was poured over them, which filled them, and they were not noticed again. In no case did they increase appreciably in size after discovery.

Very cold weather occurred suddenly on December 9, 1902. The concrete roof was entirely built, except a portion about 15 by 25 feet on the west side over the new 18-inch inlet and outlet pipe.

The thermometer dropped to 10 degrees below zero outside the reservoir. Some frost formed on the inside of the roof, adjoining the opening, and the bottom was slightly frozen. The opening was covered with a large piece of canvas and boards, and it is not known that any damage was done.

All centers not needed to close the opening, and all waste material, were removed through this opening and the last centers put in place.

January 3, 1903, the weather being suitable, the last concrete on the roof was put in place and covered to protect it from freezing. On January 13 the centers were removed and the roof was completed.

In the meantime, four inches of concrete was being placed on the bottom, including a finishing coat of American Portland cement and sand. The temperature in the reservoir was just above freezing, as shown by the following figures:

Date.	*Temperature.*	*Date.*	*Temperature.*
Dec. 11, 1902	30°	Dec. 29, 1902	34°
,, 22, ,,	36°	,, 30, ,,	35°
,, 24, ,,	36°	Jan. 1, 1903	34°
,, 25, ,,	36°	,, 2, ,,	35°
,, 25, ,,	35°	,, 12, ,,	34°
,, 27, ,,	34°		

On January 16, 1903, the sides and bottom were thoroughly washed by means of a stream from a fire hose attached to a connection in the bottom of the reservoir, water being furnished by direct pumping. The dirty water flowed off at the center of the reservoir through the new 8-inch waste pipe.

FORMS AND CENTERS.

The forms for the lower sections of the piers were of 2-inch spruce plank, planed on the inside, the grain being horizontal. They were spiked together permanently at two corners, securing three of the four sides together. The remaining side, a short one, was prevented from falling outward by a piece of furring, slightly nailed, at either end, to a 2 by 3 inch piece permanently spiked to either side of the form, near the top. At the bottom, on the lower sections, the end piece abutted against the piece of

furring nailed to the guides previously mentioned. With the 2 feet by 2 feet sections, the same method was used at the top, and a cleat, nailed to the form below, prevented the remaining side or end piece from falling outward. The pieces of furring were easily detached by a hammer, when the forms could be spread and drawn off the section of concrete.

The forms for the long section of the pier were also of 2-inch spruce plank, planed on the inside, the grain being vertical. Three sides were spiked together permanently. Planks 10 and 12 inches wide were used, 4 lengths of the 12-inch and 2 of the 10-inch being required to make the permanent portion. In addition there were enough pieces, 20 inches long and 2 inches in thickness, to make their combined width equal the height of the form. What might be called the sides of the form were composed of the planks 12 inches wide; and the back, of the planks 10 inches wide. On the front of each side a 2 by 3 inch piece, extending the length of each form, was spiked flatwise to the front of each of the side planks; ene of the 2-inch edges being flush with the outside of the form, the other projecting 1 inch beyond the inside of the form. This formed a lip which prevented the pieces 20 inches long from falling out. They were put in place with the ends pressed against the lips. (See Plate II, Fig. 1.)

This allowed the concrete to be rammed as it was put in, and not from the top, which would have been very difficult. What might be called ramming was done with a spade, and consisted in keeping the coarser material away from the sides of the form. The concrete was so wet that it needed but little ramming.

To resist the outward pressure of the concrete, the forms were clamped by short pieces of joist drawn together by iron rods having nuts and washers. When the forms were to be removed, the clamps were unbolted and removed, the form pried open on the front sufficiently to allow the projecting inch of the 2 by 3 inch piece on each side to pass the concrete. The form was then pushed away from the pier, generally at the top first, and finally taken down. Usually a man went to the top of the pier, and with a small iron bar pried the form away from the concrete.

The centering for the roof between any 4 piers consisted of four quarter sections (model shown, scale 1 inch to 1 foot).

The frame was of one length of 3-inch spruce plank, 13 feet 6 inches long and about 10 inches wide, which was the widest that could be obtained, together with 2 pieces of 2-inch plank supported by the first-named piece and forming a sort of truss; also, two side pieces of 2-inch plank and 2 ribs of the same thickness. This frame was lagged with 1-inch matched spruce, planed on top.

A full-sized outline on heavy sheathing paper was made of the ellipse, having a span of 13 feet 6 inches and rise of 2 feet 9 inches. This represents the curve of the arch from pier to pier. The curve representing the arch from pier to pier on a diagonal line was also drawn. This is an ellipse of the same rise and a span of 19.09 feet. Of course only one-half of this ellipse was used.

Curves were drawn by using very light wire having sufficient strength, with as little liability to stretch as possible. This was found to be the great difficulty, and several attempts had to be made before a satisfactory result could be obtained. The proper length of wire was used, the ends being fastened to nails at points representing the foci of the ellipse to be drawn.

Other methods of drawing the ellipse might give a little greater accuracy, but the one used was the simplest and probably all that was needed. Wooden patterns were made of the various parts, and the lumber to form the centers was sawed at a local woodworking shop. The centers were put together at the reservoir by carpenters.

These quarter sections could be easily handled by four or five good men.

Four 4-inch by 6-inch spruce uprights were placed about each pier, upon the tops of which were placed caps not less than 2 inches in thickness. The lower ends of these uprights were supported by blocking, resting as far as possible on the pier foundations.

At the center between the piers, where the four quarter sections came together, a 6-inch by 6-inch spruce upright was used, supported at the bottom by blocking. (See Plate IV, Figs. 1 and 2, and Plate V, Fig. 1.)

The centers rested upon wooden wedges, placed upon the tops of the caps. These were of great use in setting the centers at the

FIG. 1. — STAGING USED IN REMOVING CENTERS.

FIG. 2. — PIERS AND GROINED ARCHES.

proper elevation and in taking them down. A leveling instrument was used in setting the centers at the proper elevation.

Four clamps, each made of two pieces of 2-inch spruce plank, a 4-inch separating piece, and a ¾-inch bolt with washers and nut, were used on the under side of the frame of the centers, connecting adjoining quarter sections together and making the four sections practically one. (See Plate III, Fig. 2.)

It was found that without the 6-inch by 6-inch support at the center, the four sections thus united, and supported only at the four corners would carry a considerable load.

The ⅞-inch lagging was kept 1 inch away from the outside edge of the 2-inch plank, cut to form the curve from pier to pier, forming the 13 foot 6 inch span. This gave opportunity for nailing the 20-inch pieces of lagging which covered the space between one of the quarter sections and the one nearest, but not touching it. (See Plate IV, Fig. 1.) These lagging pieces were secured by small nails, sufficient to hold them in place while the concrete was being placed. In removing the centers these pieces had to be detached, and were usually left sticking to the under side of the arch till removed by a blow from a hammer, or pried off with a small bar.

When the centers were new, the concrete did not stick to them, and after being used the second time they were brushed with dead oil, which seemed to facilitate their removal.

The 4-inch by 6-inch uprights were braced by lines of 2-inch plank, extending from one slope to the opposite one. This prevented the upright from buckling, and also furnished support for a stage used to great advantage in placing and removing the centers. The centers were put together upon the bank and carried over those already placed and slid down to the staging at the desired point.

In removal, the centers were simply let down upon the stage and carried forward to their new position. No derrick or hoisting engine was used for any part of the work. (See Plate V, Fig. 1.)

The whole number of quarter sections of roof centers made was 185. If the entire roof had been centered at once, and no center used twice, 624 quarter sections would have been required, in addition to special work necessary between the regular quarter sections and the inside slopes of the reservoir.

DISCUSSION.

MR. F. W. DEAN. It has occurred to me that the concrete was rather rich for the purpose for which it was used, and I would like to ask Mr. Fuller if he could not have made it less rich.

MR. FULLER. Possibly. The piers were not of very great cross section, the load on them was quite heavy, between eighteen and nineteen tons to the square foot, at the bottom, — I suppose they would have stood more, — and the roof was only 6 inches in thickness at the crown. At the time the roof was covered it was done by driving on to it with 2-horse tip-carts which were well filled, because we had extra power for drawing them up the bank, so the horses could draw as much as could be piled on the carts. The filling was done to a considerable extent after freezing weather. The first earth that was put on was left very rough, after which considerable rain fell, and a cold spell followed, and the earth froze very rough indeed. A plowed field would not be as rough as that surface was, and as those teams went over that concrete, some of which had perhaps not been placed more than a month, and would go along and strike a hump of frozen earth and come down with great force, I felt that the concrete was none too rich. It seemed to me as though at times the teams would surely go through, but none of them did. I suppose something might have been saved, but I hardly think I should have wanted to make the concrete any less rich. It really seemed wonderful that six inches of concrete — of course it was thicker on either side of the crown of the arch — it seemed almost marvelous that that concrete could stand such heavy teaming over it. If the surface had been smooth, or if there had been a few inches of yielding material under it, it would have been different, but it was frozen solid and was as rough as it could be, and yet those teams drove over it and went up and down with very heavy loads — the carts, of course, having no springs — without apparently making any impression on it.

MR. LEONARD METCALF.* Mr. President, I have been very much interested in Mr. Fuller's paper to-night, as I have followed with great interest the growing use of the groined arch as a covering for filters and reservoirs, and the developments which have

* Civil Engineer, Boston, Mass.

taken place in it since it was first introduced into this country by Mr. William Wheeler of Boston, a member of this Association, in the Ashland, Wis., slow sand filter plant in 1895, and that of Somersworth, N. H., in 1896.

At the time of the construction of the latter plant, I had occasion to figure the quantities of masonry involved in this roof, and developed a series of mathematical formulæ therefor, which was afterwards amplified and presented in a paper before the American Society of Civil Engineers.*

Thinking that the matter might perhaps be of more than passing interest to the members of this Association, I have prepared a table of the masonry groined arch roofs which have chanced to come to my notice, giving not only a description and dimensions of the various structures, but a computation of the mean thickness of the masonry resulting from this form of construction and the cost of the roof, where such figures have been published.

It will be noticed that while there is marked similarity in the general dimensions, there have been some interesting improvements in the later work which have resulted in materially reducing the quantity of masonry or the resulting mean thickness of roof, without injury to the structure, it is believed. The most noticeable and important of these changes is that of making a depression in the masonry over the pier supporting the roof. This depression, in the majority of cases, has been in the form of an inverted pyramid of parabolic section, which is singularly well adapted for use with the elliptical groined arch intrados, though the inverted cone or pyramid has also been used. The amount of masonry to be saved in this way varies from about 10 to 30 per cent.

In some smaller roofs, as, for instance, at Clinton, or the sewage storage tank at Concord, 100 feet and 57 feet in diameter, respectively, and some others which were small, the number of piers was comparatively small, and consequently the total amount of masonry to be saved in that way was also comparatively small. Under those circumstances the actual saving to be made by depressions in the masonry over the piers is little, not only on account of the small amount of total masonry involved, but also on account of the fact that the cost of the centering is a very

* See Trans. Am. Soc. C. E., June, 1900.

DATA RELATING TO GROINED ARCHES IN THE UNITED STATES.

DATE.	LOCATION.	ENGINEER.	DESCRIPTION.	Depth of earth cover.	CONCRETE MIXED.
1895	Ashland, Wis.	Wm. Wheeler	Filters net area ¼ acre. Intrados ellip., extrados plane, 2 layers flat brick backed with concrete.	2'-0"	1: 2½: 5
1896	Somersworth, N.H.	Wm. Wheeler.	Two filters, total net area ¼ acre. Intrados elliptical extra. plane. 1 layer of br. on edge backed with concrete.	2'-6"	1: 2½: 5
1897	Wellesley, Mass.	F. C. Coffin	Reservoir 80' int. diameter. Intrados elliptical ext. plane.	2'-0"	1: 2½: 5
1898	Louisville, Ky.	Chas. Hermany	Reservoir 154,739 sq. ft. net area. Concrete reënforced with steel. Intrados and extrados segmental.	6"	1: 2: 4
1899	Concord, Mass.	Leonard Metcalf	Sewage reservoir 57 int. Diameter. Intra. ellip. extra. plane.	2'-6"	1: 2: 5
1899	Albany, N. Y.	Allen Hazen	Filters 8 beds of 0.7 acre each. Intra. ellip., extra. conical.	2'-0"	1: 3: 5
1899	Clinton, Mass.	F. P. Stearns	Sewage reservoir 100' int. Diameter. Intra. ellip., extra. plane.	4'-6"	1: 2½: 4
1899	Superior, Wis.	Allen Hazen	Filters and reservoir, total net area ½ acre, conical.	2'-0"	1: 3: 5
1901	Philadelphia, Pa. Lower Roxboro'h	John W. Hill	Filters 5 of 0.537 acre each. Also filtered water basin 153'x190'.	2'-0"	1: 3: 5
1902	Milford, Mass.	Leonard Metcalf	Filters 2 of ¼ acre each. Intra. ellip. extra. parabolic.	1'-6"	1: 2½: 5 1: 3: 5
1902	Philadelphia, Pa. Upper Roxboro'h	John W. Hill	Filters 8 of 0.7 acre each. Also filtered water basin 288'x319'.	2'-0"	1: 3: 5
1902	Natick, Mass.	Frank L. Fuller	Reservoir. Intra. ellip. extra. plane.	2'-0"	1: 2½: 4½"
1903	Ithaca, N. Y.	Allen Hazen	Coag. basin and reservoir. Intra. ellip. extra. parabolic.	2'-0"	1: 2½: 4½" 1 bbl. :9c.f.:17c.f.
1903?	Proposed for Lawrence, Mass.	Morris Knowles	Filter. Intra. ellip. extra. parabolic.	3'-0"	?
1903	Yonkers, N. Y.	Allen Hazen	Reservoir. Intra. ellip. extra. parabolic.	4'-0"	1: 2.9: 5
1903 Begun	Watertown, N. Y.	Allen Hazen	Coag. basin and reservoir. Intra. ellip. extra. parabolic.	2'-0"	1: 2.9: 5
1903	Brookline, Mass.	F. F. Forbes	Reservoir all concrete. Intra. ellip. extra. plane.	2'-0"	1: 2: 4
1903	Philadelphia, Pa. Belmont	John W. Hill	Filters 18 of 0.74 acre each. Intra. ellip. extra. parabolic.	2'-0"	1: 3: 5
1903	Philadelphia, Pa. Belmont	John W. Hill	Filtered water basin 382x396. Intra. ellip. extra. parabolic.	2'-0"	1: 3: 5
1903 Begun	Philadelphia, Pa. Torresdale	John W. Hill	Filters 33 of 0.75 acre each. Intra. ellip. extra. parabolic.	2'-0"	1: 3: 5
1903 Begun	Philadelphia, Pa. Torresdale	John W. Hill	Filters 23 of 0.75 acre each. Intra. ellip. extra. parabolic.	2'-0"	1: 3: 5
1903 Begun	Philadelphia, Pa. Torresdale	John W. Hill	Filt. water basin 602x762. Intra. ellip. extra. parabolic.	2'-0"	1: 3: 5
1903 Begun	Washington, D. C.	Col. A. M. Miller	Filters Nos. 1 to 24.	2'-0"	1: 2.9: 5
1903 Begun	Washington, D. C.	Col. A. M. Miller	Filters Nos. 25 to 29.	2'-0"	1: 2.9: 5
1903	New Milford, N.J.	Hering & Fuller	Clear water well under Mech. filters 2 sec. 47x148'.[6]	none	
1903	New Milford, N.J.	Hering & Fuller	do. do.[7]	none	
1903 Begun	Washington, D. C.	Col. A. M. Miller	P. W. Reservoir.	2'-0"	1: 2.9: 5

[1] Cost column covers cost of masonry only from springing line of roof. Earth cover and engineering not included unless so stated. [2] Earth cover, etc., included. Total exclusive of engineering only (10%†) See text. Steel reënforcement. [3] Including filling, manholes, etc., but excluding en-

PREPARED BY LEONARD METCALF, 14 BEACON STREET, BOSTON, MASS., DECEMBER 1, 1903.

ARCH.			Depression over pier, inches.	Pier Section at springing, inches, and area, sq. ft.	Volume saved by depression in cu. yds. and equal depth in in.	Mean thickness of roof. Inches.	[4]Cost per square foot. Dollars.	Pier load tons per sq. ft. above springing line. Concrete at 150 lbs. Brick at 130 lbs. Earth at 110 lbs. Snow 15.	Intrados $R = \frac{(\text{Span})^2}{8 \text{ Rise}} +$	Intrados $R = \frac{(\text{semi span})^2 + (\text{rise})^2}{2 \text{ Rise}}$.
Span.	Rise.	Cr'n Th'kn's.								
15'-9"	3'-6"	6"	none	28×23=4.42 28½×24=4.73 brick	none	11.7"		12.5	8.9'	10.6'
16'-0"	4'-0"	6"	none	34½×34=8.15 granite	none	13	$0.47	9.7	8.0	10.0
12'-0"	2'-6"	6"	none	24"×24"=4.0 brick	none	10.3	0.225	8.9	7.2	8.5-
19'-0"	3'-9.6'	6"	27.6"	Dia. 3.4'=9.0	5.45=3.7"-	11.7	0.61[2]	5.8	(11.9)	(13.8)
12'-9"	3'-0"	6"	none	24"×24"=4.0 brick	none	11.0	0.38	11.7	6.8	8.3
11'-11"	2'-6'	6"	6"	21×21=3.06 brick	0.93=1.63	8.5	0.183 0. 277[3]	11.0	7.1	8.4-
12'-0⅞"	2'-6"	12"	none	30×30=6.25 25×25=4.33 brick	none	16.8		12.2 17.7	7.3	8.5
12'-0"	2'-6"	6"	6"	20×20=2.77 brick	0.93=1.63	8.4	0.29	12.0	7.2	8.5-
14'-0"	3'-0"	6"	21"	22×22=3.36	2.7=3.5	7.3		13.3	8.2-	9.7
14'-0"	3'-0"	6"	18"	24×24=4.0	2.37=3.0	7.9	0.36[4]	9.8	8.2-	9.7
14'-0"	3'-0"	6"	21"	22×22=3.36	2.70=3.5	7.3		16.8[5] 13.3	8.2-	9.7
13'-6"	2'-9"	6"	none	20×20=2.77	none	10.2	0.40	15.1	8.3	9.7
19'-6"	1'-6"	6"	10¼"	18×18=2.25 17×17=2.01	0.75=1.70	6.78		10 9 & 12.2	9.2	9.9
13'-2"	2'-0"	6"	18"	22×22=3.36	2.08=3.0	7.5		15.6	7.9	9.2
19'-0"	1'-6"	6"	9¾"	16¾×16¾=1.96	0.65=1.6	7.0		18.5	8.3	9.1
19'-0"	1'-6"	6"	10"	18×18=2.25	0.68=1.7	6.9		9.9	8.3	9.1
12'-0'	2'-6'	6"	none	20×20=2.77	none	10.1	0.40±	12.2	7.2	8.4
15'-5"	3'-0"	6"	9"	22×22=3.36	2.51=3.5	7.3		12.4	7.5	9.0
14'-0"	3'-0"	6"	21"	22×22=3.36	2.70=3.5	7.2		13.3	8.2	9.7
14'-0"	3'-0"	6"	21"	22×22=3.36	2.70=3.5	7.2		13.3	8.2	9.7
13'-2"	3'-0"	6"	21"	22×22=3.36	2.43=3.5	7.4		12.0	7.2	8.7
14'-0"	3'-0"	6"	21"	22×22=3.36	2.70=3.5	7.2		13.3	8.2	9.7
12'-2"	2'-6"	6"	17"	22×22=3.36	1.70=2.8	7.3		9.7+ sand stored	7.4	8.6
11'-10"	2'-6"	6"	17"	22×22=3.36	1.63=2.8	7.4		9.1+ sand stored	7.0	8.2
9'-9"x 11'-9"	2'-6"	8"	none	24×24=4.0	none	11.7		30±?	4.7 6.8	5.9 8.1
11'-9"x 12'-0"	2'-6"	8"	none	24×24=4.0	none	12.3		30±?	6.8 7.2	8.1 8.4
13'-6"	3'-6"	6"	24¾"	30×30=6.25	4.0=1.5	7.9		8.7+ storage	8.6	10.3

gineering. [4]Cost per square foot is estimated from force accounts; contractor's price was less (poor management). [5]Including sand stored upon roof. [6]¼ of clear well with these arches. [7]⅓ of clear well with these arches.

large proportion of the total cost of the masonry roof. If, on the other hand, the centering may be used over and over again, if the area is large enough, as was the case in the Albany work and the Philadelphia work, — and I think Mr. Fuller said in the Natick work, — the proportionate cost of the centering is not so large and the saving which will result from the depression over the piers is greater of course; while in the smaller structures, where the cost of centering is larger proportionally, the saving is proportionally smaller. It will generally be found that a decided net saving will be effected.

Each case, however, must be decided on its own merits, and various considerations may govern the engineer in his choice of design. Thus, the disadvantageous character of the ground in which the structure is built may make it desirable to have the greater stiffness and beam action resulting from building the extrados as a plane. Again, the area to be covered by the roof may be so small as to make the actual saving by depressing the roof over the piers insignificant. Or, proximity to other structures, with resulting unequal distribution of loading of the ground about the structure, or lack of homogeneity in the material surrounding it, may make the element of beam action in the roof of greater importance. Or, the necessity of storing sand upon the roof for lack of other room may make greater strength necessary; or, the side walls may be designed as beams to be built of concrete with embedded steel, as in the clear water basin and sedimentation tank which has just been completed at Ithaca, N. Y., — in which case the roof must act not only as an arch, but also as a beam to take the thrust coming from the walls; or questions of drainage may be of primary importance.

For these reasons, it is by no means safe to criticise different designs simply on the basis of the amount of masonry involved, without knowing fully the local conditions attending the work. Moreover, in glancing back at the old work, the first of which was constructed of brick masonry, re-enforced with concrete, the fact must not be lost sight of that the work was novel at the time of its construction, and that the excellence of concrete as a building material, when judiciously handled, had not been so well demonstrated as it has by the more general use in recent years; the price of cement was also considerably higher than to-day.

It is interesting to note that in the later designs, not only have depressions been made over the piers, but the sections of the piers have been decreased, with resulting increase in unit load per square foot borne by the pier; and the amount of cement used, or the richness of the concrete, has been materially decreased.

Moreover, in some of the recent designs circular piers have been used or proposed in place of the square ones, with square capitals upon them. While the writer was of the opinion that the use of the latter form would probably not result in any material saving in cost, on account of the greater difficulty in forming the capital for the column, he was interested to hear that in the recent plans for the proposed filter plant of Pittsburg, Pa., not yet built, quotations were obtained upon both forms of piers, and it was found that the unit prices were substantially identical, which would result, if not in an actual saving of cost, at all events in a better distribution of the material in the pier.

I should be very much interested to hear from Mr. Fuller in regard to the reasons which led to his adoption of the horizontal surface in this case, for I have no doubt he considered the saving which might have been effected in the way I have indicated.

The first arches which were built, those at Ashland, Wis., which, as I have said, were built in 1895, had a span of 15 feet 9 inches; a rise of 3 feet 6 inches; a crown thickness — as has been the case in almost all of these arches — of 6 inches. The pier section of the Ashland filter was about 4.4 square feet; that is, it was 2 feet 4 inches by 1.9 feet. This resulted in a net load on the pier, — figuring on the basis of concrete at 150 pounds per cubic foot, brickwork at 130 pounds, earth at 110 pounds, and snow at 15 pounds per square foot, — or a unit load at the springing line (not at the base of the pier) of 12½ tons per square foot. The surface of that arch is a plane surface. The arch was built with two courses of brick laid flat, that is, on the bed, covered with concrete, bringing the extrados up to a level surface, and giving six inches of masonry at the crown of the arch. That resulted in a mean thickness of the roof, figuring all the masonry above the springing line, and not making any deduction for manholes, of 11.7 inches. The concrete used was mixed in the proportions of 1 : 2½ : 5.

At Somersworth the proportions of the concrete were the same; the span was 3 inches longer, that is, 16 feet; the rise was 4 feet; the piers were built of granite, — whereas in Ashland they were built of brick, — and the section contained 8.15 square feet. The net load resulting, with an earth filling of 2½ feet in depth, was 9.7 tons per square foot. There resulted a mean thickness of about 13 inches of masonry. In that case the roof was constructed of one course of brick laid on edge, surmounted by a layer of concrete, bringing the extrados surface to a horizontal plane.

These filters were built, of course, before concrete was used as it is to-day. They were the first roofs of the kind that were built in this country; they were, indeed, substantially the first roofs of the kind that had been built anywhere. Of course the groined arch had been used in architectural work and in some large spans abroad, but not in quite this way.

The next structure of the kind which was built was the Wellesley reservoir, by Mr. Coffin, in 1897. It was circular, only 80 feet in diameter, small, you see, with the same proportions of cement, sand, and stone in the concrete; with a span of 12 feet, a rise of 2½ feet, a pier section of 4 square feet, that is, 2 feet by 2 feet of brick, resulting in a unit load of 8.9 tons, and a mean thickness of 10.3 inches. You see the mean depth of the masonry is decreasing. This was moreover the first structure of the kind in which the roof was built entirely of concrete.

Then there was built in 1899 the sewage storage basin, so-called, at Concord, with a mean thickness of 11.7 inches and a pier load of 11.7 tons. In that case the surrounding material was exceedingly bad, the structure was of small dimensions, and there was a pumping station with comparatively heavy loads right beside it; for this reason no depression was made in the roof masonry over the piers.

In 1898–9 the Albany filter plant was built by Mr. Hazen, whose resident engineer, Mr. William B. Fuller, is here to-night, and will perhaps tell you what sort of service or treatment some of those arches received. The proportions of the concrete were 1:3:5, as I remember, with a span of 11 feet 11 inches and a rise of 2½ feet, with piers 21 inches by 21 inches, giving a mean depth of 8.5 inches and an average load of 11 tons.

Then followed the Clinton sewage reservoir, built by the Metropolitan Water Board in 1899. The arches had a very heavy load over them, the depth of earth being 4½ feet. The bottom on which they were constructed was exceedingly bad, with possible danger of floating the structure, and evidently they were anxious about the loads on the arches and the character of the material surrounding the structure, because the proportions of the concrete were very rich, being 1:2½:4. The crown thickness was 12 inches. This gave a mean depth of 16.8 inches and a load at the springing of 12.2 tons and at the minimum section of the piers, just below there, of 17.7 tons.

Then followed the filters at Superior, Wis., built in 1899 by Mr. Hazen, in which the mean thickness was 8.4 inches and the load 12.0 tons.

In 1901 came the Philadelphia plant. The proportions of concrete were there 1:3:5, the mean thickness was 7.3 inches, and the pier load 13.3 tons to the square foot. In that case the depression over the pier was 21 inches, and the saving was approximately 2.7 yards of masonry to a pier, which was equivalent to 3½ inches over the section covered by the pier. You see how much that means. As I remember it, it figures out something over 30 per cent. of saving.

Then came the Milford plant, which was built in 1902, in which the depression was 18 inches and the mean thickness 7.9 inches and the load 9.8 tons per square foot. I might say that in that case there was very little room about the filter for storing the sand, and we thought that possibly it might be necessary to store the washed sand from the filter on top of the filter roof itself, and so figured on a depth of four feet of sand spread over the filter roof, which brought the load up to 16.8 tons per square foot. It was for that reason also that the piers were made a little heavier than originally designed, that is, 2 feet square, while my original plans called for an 18-inch pier.

Then followed the Upper Roxborough plant in Philadelphia, which was identical with the Lower Roxborough plant, giving 7.3 inches mean depth.

Then came the Natick reservoir, with, as I have figured it, a mean thickness of roof of 10.2 inches, and a load of 15.1 tons per square foot at the springing line — not at the base of the pier.

And last of all, is the Ithaca plant, designed by Mr. Hazen which has just been completed, and about the dimensions of which I am a little in doubt. My impression is that the depression over the piers is about 6 inches (actually 10¼ inches). If that is the case, the average depth in thickness of the masonry would be 7½ inches (actually 6.8 inches) and the load from 10.9 to 12.2 tons per square foot.

It is interesting, too, I think, to see the decrease in the section of the piers and the resulting increase in the unit loads. Engineers generally, I think, have not come yet to the heavy unit loads on concrete piers that some of the concrete construction companies have used, one or two of which, I remember hearing, amounted to 33 tons to the square foot on piers 12 by 12 inches. Of course that seems entirely feasible if the material is good, and if you are perfectly sure of your work, in view of the concrete tests that have been made at the Watertown Arsenal and elsewhere.

I hope Mr. William B. Fuller will say something to us about the Albany plant, particularly in view of what Mr. Frank L. Fuller has said about driving teams over the groined arches. My recollection is that I saw a 5 or 7-ton roller in use on the roof of the Albany filter plant, and I do not think that the concrete was injured by it. He knows the facts.

Mr. Leonard Metcalf (by letter).* The writer has ventured to supplement his discussion of Mr. Fuller's paper by certain additional data which may be of interest in bringing information down to date, and as being of historical value in the study of the development of the groined arch roof in engineering structures in the United States. In this he has been materially assisted by contributions from Mr. Charles Hermany of Louisville and Mr. Allen Hazen and Mr. John H. Gregory of New York, who have furnished him with new material and have kindly consented to the publishing of some of the interesting facts mentioned by them relating to the construction of plants designed by them.

In comment upon the table, one or two facts should be mentioned. The " Mean Thickness of Roof, Inches " is figured on the basis of the amount of masonry above a horizontal plane passing through the springing line of the roof arches and contained within the area covered by pier units. No account is taken of the

* Received December 11, 1903. — Editor.

masonry in the pier below this plane or of the masonry in the floor. No allowance is made for the increased amount of masonry used in the barrel or the cloistered arch along the walls surrounding the area covered by pier units, as the pier unit area was thought to be the better unit of comparison. Neither was allowance made on account of manholes or sand runs. These elements — manholes, sand runs, barrel and cloistered arches, — will be found in ordinary large units to increase the average thickness of the roof above the springing line, as determined from the pier units, by about ½ to 1½ inches.

The " Cost of the Roof per Square Foot " in general covers only the cost of the masonry, including therein materials, labor, centering, and removing centering, etc. (above springing line of roof), but does not include the cost of earth covering and of engineering.

In the last two columns has been computed a function of these arches which have been built, a function that many engineers must have noticed, though, so far as the writer knows, Mr. Hazen was the first to specifically allude to it in a letter to him dated October 6, 1903. In this Mr. Hazen writes:

> In your table of vaulting there is one point of some interest to me; namely, that the circle having the same curvature as the ellipse at the top, the radius of which is obtained by squaring the span and dividing by the rise, is, for all figures listed in your table, somewhere nearly a constant; at least it varies a good deal less than any of the other dimensions do. This indicates approximately a constant thrust and a constant strength of vaulting per square foot of area when it is computed acting entirely as an arch.

This relation, which briefly consists in finding the radius of a circle passing through the crown and the springing lines of the elliptical groined arch, is, of course, one long known to railroad engineers, who have made use of the approximate formula:

$$\text{Middle ordinate} = \frac{\text{Chord}^2}{8 \times \text{Radius}}$$

from which, by transposition, we have

$$\text{the Radius} = \frac{\text{Square of Span}}{8 \times \text{Rise}}$$

This value, figured by the writer and shown in the left of the two columns mentioned, led him to compute the more exact value

of this radius from the relation of similar triangles, which gives the formula:

$$\text{Radius} = \frac{(\text{Chord of semi-span})^2}{2 \times \text{Rise}} = \frac{(\text{Semi-span})^2 + (\text{Rise})^2}{2 \times \text{Rise.}}$$

While both of these values are empirical,—for the arches have generally been segmental, not elliptical,—they are of interest and serve as guides to judgment in design. The average value of the radius (shown in the right column) as determined by omitting the Louisville arches — which contained embedded steel — and the New Milford, N. J., arches, — which have an abnormally heavy superposed load, a mechanical filter plant, — is found to be

$$R = 9.17 \text{ feet,}$$

while the extremes of conservative and radical practice (though in the writer's opinion the radical class of to-day will become the conservative class of the next decade), show approximate values of R = 8.5 and R = 10 feet.

Mr. Hazen writes in regard to the Albany filter roof:

I see at Albany the extrados is marked parabolic. This was true of the outside and cross walls, but the depression over the piers was made conical. The cone, however, did not start exactly at the summit, but at such a point as not to reduce the thickness of the arch below six inches, and, in fact, the minimum due to the cone was a little more than this figure. From my final estimates the volume of the depression was 25.219 cubic feet. The volume equal to a square six inches thick was 93.389 cubic feet, and the volume of the vaulting from the pier up to the bottom of the 6-inch slab was 64.065 cubic feet, making the exact volume over each pier 132.235 cubic feet, which corresponds to a thickness of about 0.71 foot.

Another computation which I made February 9, 1899, gives:

Reduced thickness of vaulting over piers in filters	0.71 foot
Over piers in pure water reservoir (no depression)	0.84 "
Outside walls	0.81 "
Cross walls	0.90 "
Other cross walls	0.83 "
Outside corners	1.06 "
Inside corners	1.54 "
Manholes (Distributed over whole area)	0.029 "
Sand runs, about 0.5 foot extra over gross area of same.	
Average thickness of vaulting, including all extras on net area	0.77 "

I see that in discussing your paper on "Vaulting" I gave the reduced thickness as 0.78. This latter computation was made some months later, and I

do not find memoranda of it, but I do find that the total quantity of concrete in the vaulting as allowed in the final estimate overran the amount which I estimated in my computation of February 9, 1899, by about one per cent.; so that the figure given, namely, 0.78, is apparently the correct one.

Apparently this was the first time that the depression over the piers was used, and I do not think it occurred to us to make it parabolic. We did make some designs for curves, but my recollection is that we thought the conical surface would be a good deal easier to build and would accomplish [substantially the result to be reached as well as a curved surface.

The sections of the vaulting over the outside and cross walls vary a little in different parts of the work. I have a large scale plotting of these sections as they were actually built, which I had made at the time, partly for the purpose of the final estimates and partly as a permanent record of exactly what was used.

For the amount of depression that we used at Albany, I still think the conical depression is better than the parabolic, but for the deeper cuts which have since been made it will not do, and I have thus used the parabolic curves on all my later designs.

Upon the Superior plant he says:

The depression over the piers at Superior is the same as at Albany, and amounts, as I compute it, to 1.63 inches instead of 1 inch, with a corresponding reduction in the distributed thickness of the vaulting.

In regard to the Yonkers and Watertown, N. Y., plants, he writes:

The Watertown piers were made a little larger relatively than usual, because they were rather high, and the Yonkers piers were considerably smaller than usual, being about normal for the 2-foot cover. Putting the extra weight on the vaulting, of course, runs up the load per square foot a good deal. The increased thickness of covering in this case was an afterthought, which facilitated some other matters, and the size of the piers was not changed. At Yonkers the fill was made 4 feet, the extra depth being partly as a dike to protect against floods and partly as a load to prevent possible floating with high ground-water and with the reservoir empty.

While the smaller piers at Yonkers are undoubtedly amply safe, the saving in material does not amount to much, and next time I should make them uniform with the others. The curve of the roof is identical in the two designs, but there is a slight difference in the drop to correspond with the longer span at Watertown.

The above dimensions are the nominal dimensions. In actually laying the thing out I usually make the forms slightly shorter than the schedule, so as to give the contractor a little come and go. This facilitates the work greatly, and the increased amount of concrete does not amount to much. When the piers are just right or are out in the wrong direction, of course this

leaves a crack between the top of the pier and the center, which ought to be plugged before the concrete is placed.

In comment upon the Washington filters, Mr. Hazen writes:

While it is not intended to store sand on this vaulting, it was intended to be strong enough so that the vaulting could be loaded pretty freely in this respect, and so that light tracks could be laid upon it.

Mr. Charles Hermany, engineer of the Louisville, Ky., Water Company's water purification station at Crescent Hill, Ky., gives the following interesting and exceedingly valuable detailed account of that work:

The year is given as 1898 because the design and dimensions were determined then and afterwards carried out without deviation. The work was completed in 1900.

Both the arches and columns are stronger than necessary, were they only to support themselves and the earth filling. This has been proven by building upon the groined arches a concrete bed 8 inches thick over the crown, in which a track is built of standard steel rails, 80 pounds to the yard, and loaded freight cars pushed over it with a combined dead and live load (car and freight) of five tons to the car-wheel without visible effect upon arch or colums. When designing these arches it was not apprehended that it would be desirable or necessary to run cars across them.

Great misgiving was manifested by contractors as to the practicability of building reliable columns of this description. The successful and satisfactory building of them proved to be one of the easiest and simplest tasks connected with the reservoir.

The concrete was machine-mixed, but all the manual labor was performed by crude and unskilled men, with which difficulty was experienced in satisfactorily building the arches; it was accomplished only by constant and vigilant engineering supervision. With the experience gained in this work, entirely satisfactory results could be obtained with reduction in both volume of concrete and cost of construction.

The solidifying of the concrete by tamping was done by hand, in layers of about 4 inches in thickness at a time. Better results have since been accomplished by reducing the thickness of layers and using pneumatic tampers.

MEMORANDUM OF FEBRUARY 8, 1902.

THE CLEAR WATER RESERVOIR AT THE LOUISVILLE WATER COMPANY'S WATER PURIFICATION STATION AT CRESCENT HILL, KY.

		Sq. ft.
1. Total area of quadrangular space covered by the outside dimensions of the structure		180 740
2. Area covered by the four retaining walls	18 541	
3. Area covered by the three division walls	4 460	
4. Area covered by 256 columns supporting the groined arches	3 000	
5. Aggregate area of water surface in the four compartments	154 739	
Total		180 740

which water surface is the area roofed over by the groined arches. The groined arches are 340 in number, 270 of which are square, 22 by 22 feet span between centers of columns, and 70 arches are in one direction of 22-foot span, and at right angles thereto of variable span, — both greater and smaller than 22 feet, — owing to the quadrangular plan of the reservoir not being a square but a trapezoid.

In the following table are given the items which comprise the cost of constructing the arched covering to the clear water reservoir, subdivided into ten different classifications of material and work.

TABLE.

	Per sq. ft.
1. 2446.93 c. y. Portland cement 1-2-4 concrete in columns, at \$7.10, $\frac{\$17,373.20}{154\ 739}$ =	\$0.112
2. 333.32 s. y. Portland cement 1-2 mortar in columns, at 29 cts., $\frac{\$96.66}{154\ 739}$ =	0.001
3. 7484.11 c. y. Portland cement 1-2-4 concrete in arches, at \$7.10, $\frac{\$53,137.18}{154\ 739}$ =	0.343
4. 978.13 s. y. Portland cement 1-2 mortar in arches, at 42 cts., $\frac{\$410.81}{154\ 739}$ =	0.003
5. 168 750 lbs. steel ribs in concrete arches, at 3¼ cts., $\frac{\$5,484.40}{154\ 739}$ =	0.035
6. 7325.89 s. y. neat Portland cement mortar one-eighth inch thick plaster on columns, 23 cts. $\frac{\$1,684.95}{154\ 739}$ =	0.011
7. 18 444.87 s. y. neat Portland cement mortar one-eighth inch thick plaster on soffit of arches, 23 cts., $\frac{\$4,241.40}{154\ 739}$ =	0.027
8. 3928.04 c. y. earth fill over arches, 30 cts., $\frac{\$1,178.41}{154\ 739}$ =	0.008
9. 154 739 s. f. sodding, at 10½ cts. per s. y., $\frac{\$1,805.29}{154\ 739}$ =	0.012
10. Centers for arches and falseworks, $\frac{\$9,000.00}{154\ 739}$ =	0.059
	\$0.611
Less correction	0.001
Total cost per square foot of covering	\$0.610

In the above, items 2 and 4 are for mortar used to interpose between successive additions of concrete, so as to make such additions adhere to each other.

The foregoing ten items of cost comprise the total amount paid by the Water Company to the contractor, to which wants to be added the cost of inspection and engineering supervision, which amount is not exactly known, but will approximate closely to ten per cent. of the cost.

MR. WILLIAM B. FULLER.* Mr. President and gentlemen: The strength of a concrete groined arch is very difficult if not impossible of calculation, as a satisfactory theory of the stresses in such a structure has not as yet been developed. Our knowledge of the strength of such groined arches is based, therefore, to a large extent, on their behavior under conditions of greater stress than ordinary conditions, and it is to be commended, therefore, that the author has described the treatment in this respect, which his arches have received. The speaker also has had cases on his own work where groined arches have been accidently exposed to heavier loading than they were expected to carry, without any bad effects.

It seems to be a universal practice to make the thickness of the crown of the arch six inches, probably because in practice this is about the minimum thickness of concrete which can be placed with ordinary labor and with the same concrete as used in the more massive part of the work. A less thickness at the crown would call for greater care in placing and small diameter stone in the concrete, which would increase the cost per cubic yard and thus possibly offset the saving in quantity. There is, however, no reason except this practical one why the crown of the arch should not be made much thinner.

Several years ago, while superintending the construction of concrete groined arches at the Albany Filter Plant, the speaker made up and tested the strength of a few small models. These tests indicated that a groined arch of about 13 feet span, 3½ feet rise, and 6 inches thick at the crown, after being built thirty or more days, would safely sustain without any danger of fracture of the arch a load of brick piled on top of the arch 40 feet high. At Albany a three-ton road roller was repeatedly run over the arches previous to the placing of the dirt and within thirty days after the concrete was placed. At another time the contractor placed a derrick bringing a concentrated load of nearly two tons on about one square foot in the center of the arch. Heavily loaded two-

* Civil Engineer, New York, N.Y.

horse wagons drove over the arches in all directions with ut restriction, sometimes within two weeks of the placing of the concrete.

At Philadelphia a road roller weighing several tons and drawn by four horses was driven over an arch which had been cut along its crown so that it was simply a cantilever extending out from the piers about 7 feet; that is, this arch was built only to the line where the author explained that he stopped his concrete during a day's work. The centers were removed and the roller passed over the half arch about thirty days after the concrete had been placed. An illustration of this is being used by one of the cement companies for advertising purposes.

The speaker would suggest a few improvements in relation to the author's centering which he has observed as in use at Philadelphia. Instead of placing four 4-inch by 6-inch posts at each pier extending from the floor of the filter to the under side of the centering, a great saving can be made in lumber by simply clamping a collar around the top of each pier on which the centers rest directly, without using any posts whatever. Instead of using 6 pieces of centering at each groin unit it would be better to make this unit in four parts, the lines of division extending square across from center to center of piers and diagonally from corner to corner of piers; by this method only one post is needed, that at the intersection of the diagonals from each pier, for holding up all four centers, each center resting on the clamps around each pier and on this center post. The economy of this method is particularly noticeable on deep and large reservoirs, as in such a case the centering can be used over and over again.

There is one point which Mr. Metcalf did not clearly bring out in relation to the saving in the concrete by leaving depressions over the piers. Depressions have been more frequently used over the piers of slow sand filter plants, because the water which would collect in such depressions can be run right down into the filters. In the case of a clear water reservoir, such as described by the author, it may not be desirable to run the surface water into the reservoir, and in such a case the depressions must be made water tight.

In Philadelphia, where depressions were left in the concrete

over the piers of the clear water reservoirs, such depressions were filled with clay puddle and of course the cost of the puddle should be deducted from the cost of the concrete saved in order to obtain the net saving.

MR. F. W. DEAN.* I think one interesting thing in regard to this matter is that it furnishes some additional illustrations of the frequency with which concrete construction is being carried on nowadays. It struck me, in listening to the description which Mr. Fuller gave of the groined arches, that they might be cast so as not to require any ramming whatever. That brought to mind having seen quite recently the process of building the Stadium at Harvard College, which is a large auditorium surrounding the football ground and designed to seat, I think, something like 50 000 persons. The architectural features were designed by McKim, Mead & White of New York, and the engineering features by the staff of the Lawrence Scientific School. There they have columns which I should think are some 20 inches square, made hollow, 4 inches thick; and the seats are being moulded just as cast iron is moulded, that is to say, they make patterns, as they would if they were making iron castings, then mix up sand and cement and pour it into the moulds, which are made in sand exactly as an iron mould is. They use for adding somewhat to the strength of these seats a framework of steel wires, which, I believe, where the wires cross each other at right angles, are welded by some process or other, and there they are casting thousands of those seats.

There is one thing I should like to know from Mr. Fuller, and that is, the gage of the stone which was used in his arches. I believe that was not mentioned by him.

MR. FRANK L. FULLER. As I remember, the specifications called for stone not over 2½ inches in its longest diameter, but, as a matter of fact, I think a good deal larger stone was used, and I really see no objection to it. I think perhaps we had a small amount of stone which was 4 inches in diameter, stone which had been screened out of a gravel pit. It was good, clean, solid stone, and I was not very particular about the size of it.

I should just like to say a word in regard to another reservoir which I am building, where the walls are entirely of concrete,

* Mechanical Engineer, Boston, Mass.

2½ feet at the top and 3½ feet at the bottom, where the specifications allow 40 per cent. of stone to be bedded in the concrete. That wall is now finished, and apparently it is a good, sound piece of work. I do not know why in such piers as we are building, 20-inch piers and 24-inch piers, good, sound stone could not be put in. It would reduce the cost considerably, and I think would still give good work. The weight of the piers would not be reduced, and I do not see that their strength would be; and perhaps the same thing could be done in the filling over the piers. I know in certain work which is being done, for instance, the core wall of the Lynn dam, which was built partly last season and is being completed this season, or is now completed, a good many stone of considerable size were placed in that wall, which was, perhaps, — I cannot give the exact thickness, — 6 or 8 feet thick at a distance 15 or 20 feet below the top. I am not sure that these figures are exact, however.

Mr. F. L. Fuller (by letter). While the writer has had no experience in the use of collars clamped to the top of concrete piers to support the centers, referred to by Mr. William B. Fuller, he has supported centers for lintel arches between brick piers successfully, by corbeling out the upper courses of bricks. The centering was, however, very light and the span short. These piers and arches supported a 12-inch brick ring, which in turn supported covering arches. Before the covering arches were built, however, the piers had been tied together at the top, so that no lateral movement was possible, and the Portland cement brickwork well set.

In the case of concrete piers and a groined arch roof, it would appear to the author safer to support the centers independently of the piers, as is the case where four 4 by 6 inch timbers resting on the pier foundations are used. It is often desirable to put the concrete roof in place before the piers have had time to become sufficiently set to bear the combined weight of centers and concrete roof.

It would seem that there might be a possibility of bending action, especially when the loading of the centering on different sides of the pier was unequal, which would be detrimental It must be borne in mind that newly made concrete, especially with the increasing tendency to make it less rich and reduce the area of sections deserves careful treatment.

If, however, actual experience shows the method to be practical, there would be some saving in the cost of centering. At Natick centers were put in place around piers which were perhaps not more than five or six days old. In such cases, at least, it would seem best to the writer that these centers be supported independently of the piers.

By the time the centering is removed the piers have become solidified, and so joined together at the tops that, as in the case previously mentioned, there is no chance for lateral motion.

Further, these 4 by 6 inch timbers at each pier supporting the centers formed the means of also supporting a stage, as described on page 397, which was of great service.

Referring still further to Mr. Wm. B. Fuller's suggestions on page 413, the author would say that the four quarter sections of the Natick centering filled that part of the groin arch unit lying between the corners of the four surrounding piers. The four quarter sections of centering came together at the intersection of the diagonals from corner to corner of piers, and at this point required but one support, which at Natick was a 6 by 6 inch spruce timber, as described on page 396. The point of intersection of the diagonals, or the point at which the four quarter sections come together, is shown on Plate III, Fig. 2, the 6 by 6 inch support having been removed at the time the photograph was taken. The author's centering at Natick was bounded by three sides, and was simple in construction — but four pieces or sections were used within the square bounded by four piers. In addition were the 20-inch pieces of lagging, extending from one section to another and bridging the space by which they were separated. These short laggings were used over and over again, and were quickly put in place. The centering as used was very satisfactory in practice, and the author doubts whether much improvement could be made in it.

The sections or pieces of centering referred to by Mr. W. B. Fuller were apparently bounded by five sides, two of which were equal in length to one half of the side of the pier, and the other three, provided the span was the same, of the same length as those used at Natick. Apparently they would require a little more lumber, while the amount of lagging would be the same in either case.

In regard to depressions over piers, the author believes a saving can be made, especially in large roofs, and that in many cases the idea can and should be carried out. At Natick so little time was available to prepare plans and specifications in order that the work might be begun in time for its completion before winter that the question did not receive much consideration.

There are, of course, some objections to these depressions. Some care and attention are necessary on the part of both engineer and contractor or his workmen in forming them. If they are not uniform in size, for any cause, the volume of each depression must be measured, provided the work is done by contract. Probably not quite so wet concrete could be used. The depression forms a pocket for the collection of rain water which will probably find its way into the reservoir. This objection is, however, hardly worth considering, provided the covering material is free from anything liable to injure the water. If the roof were covered by means of teams, they could not drive over the tops of the piers with full loads, on account of the depressions, and a little more shoveling in leveling the top might be required.

PROCEEDINGS.

Twenty-second Annual Convention.

Montreal, September 9, 10, 11, 1903.

The twenty-second annual convention of the Association was held in Montreal on Wednesday, Thursday, and Friday, September 9, 10, and 11, 1903. The headquarters of the Association during the convention were at the St. Lawrence Hall, and the meetings were held in one of the large parlors of the hotel.

The following members and guests were registered:

Members.

S. A. Agnew, K. Allen, F. E. Appleton, M. N. Baker, L. M. Bancroft, J. E. Beals, J. F. Bigelow, F. E. Bisbee, George Bowers, E. C. Brooks, Fred. Brooks, L. Z. Carpenter, E. J. Chadbourne, Wm. F. Codd, M. F. Collins, M. A. Connell, F. H. Crandall, G. K. Crandall, J. W. Crawford, A. W. Cuddeback, J. M. Davis, F. W. Dean, E. D. Eldredge, E. A. Ellsworth, August Fels, Murray Forbes, F. L. Fuller, W. B. Fuller, D. H. Gilderson, A. S. Glover, F. H. Golding, W. J. Goldthwait, J. W. Goodell, A. A. Gould, F. W. Gow, J. O. Hall, J. C. Hammond, Jr., J. D. Hardy, G. H. Hart, V. C. Hastings, W. E. Hawks, D. A. Heffernan, W. R. Hill, H. G. Holden, H. R. Johnson, Willard Kent, G. A. King, A. A. Knudson, C. F. Knowlton, E. S. Larned, H. A. Lord, H. V. Macksey, J. A. Marion, A. E. Martin, A. S. Merrill, F. E. Merrill, Leonard Metcalf, J. T. Miller, J. W. Moran, W. W. Patch, F. L. Northrop, W. Paulison, E. L. Peene, F. H. Pitcher, J.-B. Putnam, C. E. Riley, G. A. Sanborn, W. F. P. Sealy, E. M. Shedd, C. W. Sherman, M. A. Sinclair. G. H. Snell, J. F. Sprenkel, G. A. Stacy, R. J. Thomas, H. L. Thomas, W. H. Thomas, J. L. Tighe, D. N. Tower, C. K. Walker, C. S. Warde, R. S. Weston, W. P. Whittemore, E. T. Wiswall, D. B. McCarthy, S. H. McKenzie. — 86.

Associates.

Ashton Valve Co., by C. W. Houghton; Harold L. Bond & Co., by Harold L. Bond; Builders Iron Foundery, by F. N. Connet; Chadwick-Boston Lead Co., by Charles N. Fairbairn; Garlock Packing Co., by F. E. Putney; William H. Greenwood; Hersey Mfg. Co., by Albert S. Glover, J. A. Tilden and W. A. Hersey; International Steam Pump Co., by Samuel Harrison; Henry F. Jenks; Lamb & Ritchie, by A. P. Briggs; Lead-Lined Iron Pipe Co., by T. E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; H. Mueller Mfg. Co., by F. B. Mueller and W. L. Dickel; National Meter Co., by J. G. Lufkin;

Neptune Meter Co., by H. H. Kinsey and D. B. McCarthy; Norwood Engineering Co., by H. W. Hosford; Pittsburg Meter Co., by T. C. Clifford; Rensselaer Mfg. Co., by Fred S. Bates; Ross Valve Co., by William Ross; A. P. Smith Mfg. Co., by Anthony P. Smith, D. F. O'Brien, and John W. Strackbein; Sumner & Goodwin Co., by F. D. Sumner; Thomson Meter Co., by Henry C. Folger and S. D. Higley; Union Water Meter Co., by F. L. Northrop; United States Cast Iron Pipe & Foundery Co., by W. B. Franklin; Walworth Mfg. Co., by George E. Pickering; R. D. Wood & Co., by C. R. Wood. — 33

GUESTS.

Thos. Anderson, F. N. Collins, Mr. and Mrs. J. J. Desmond, Mrs. F. E. Appleton, Mrs. George Bowers, Miss Helen E. Bowers, Mrs. L. A. Buckman, R. G. Barnard, Mrs. V. G. Barnard, M. J. Dowd, Mr. and Mrs. Patrick Kelley, Mrs. Charles S. Proctor, Mr. and Mrs. E. H. Scribner, Miss Ellen M. Weaver, Frank L. Weaver, Mrs. Robert J. Thomas, Lowell; Thomas Burke, Mrs. J. F. Bigelow, Miss J. E Fletcher, Mr. and Mrs. J. E. Warren, L. M. Hudson, Mrs. George A. Stacy, Marlboro; Mr. and Mrs. James P. Bacon, Mrs. E. C. Brooks, Cambridge; Wm. T. Barnes, J. M. Ham, Mrs. H. V. Macksey, Mrs. H. H. Kinsey, Miss Corabelle Robbins, Thomas P. Taylor, G. A. Titcomb, Boston; F. K. Begbir, Lindsay, Ont.; Richard Bradley, Branford, Conn.; Donald B. Brigham, Brookline; Mrs. J. E. Barclen, Mrs. J. Herbert Cushing, Mrs. Harold L. Bond, Malden; Joseph M. Birmingham, Hartford, Conn.; Susette C. Berry, A. W. Danforth, Lucy A. Danforth, Reading; Miss Stella Bent, Mrs. James A. Tilden, Hyde Park; Leroy Brown, Mr. and Mrs. Fred C. Gifford, Minnie A. Gifford, George W. Furbush, Waltham; Mrs. Wm. F. Codd, Nantucket; Charles E. Child, Mrs. George E. Pickering, Howard R. Pickering, Mrs. E. M. Shedd, Marion Merrill, W. M. Rea, Somerville; Mrs. George K. Crandall, New London, Conn.; Mark Dean, New York City; Harvey D. Eaton, Waterville, Me.; Mr. and Mrs. Wells Lathrop, Mr. and Mrs. A. M. French, Mrs. E. A. Ellsworth, Holyoke; Mrs. Horace G. Holden, Mr. and Mrs. M. J. Fletcher, W. H. Greenleaf, W. N. Gates, Chas. R. McQuesten, Nashua, N. H.; Mrs. Murray Forbes, Greensburg, Pa.; Mrs. Carrie L. Fuller, Paterson, N. J.; Miss Charlotte A. Gedge, Anderson, Ind.; Mrs. Fred W. Gow, Medford; Frank J. Gifford, Fall River; Henry Goldmark, Engineer Canadian Pacific Railway, Jas. M. Ward, R. R. Samuel, representing the *Canadian Engineer*, J. T. McCall, Mr. G. B. Mitchell W. C. Leitch, Superintendent Montreal Water & Power Co., Thomas W. Lesage, Assistant Superintendent Montreal Water Works, George Janin, Superintendent Montreal Water Works, Milton L. Hersey, M.Sc., City Analyst, Montreal, Canada; Emmanuel May, Valleyfield, Que.; Mrs. G. H. Hart, Maynard; Mrs. Wm. E. Hawks, Bennington, Vt.; F. E. Hunter, West Newton; Fred W. Ingersoll, Gloucester; Miss Kent, Woonsocket, R. I.; Mrs. Willard Kent, Narragansett Pier, R. I.; Arthur C. King, Taunton; Mrs. Harry A. Lord, Odgensburg, N. Y.; Mrs. D. B. McCarthy, George H. McCarthy, Miss Edith McCarthy, Waterford, N. Y.; Mrs. Mary Folger Wells, Miss Julian, Brooklyn, N. Y.; Walter E. Lautz, Secretary Pekin Water Works Co., Pekin, Ill.; Mrs. S. H. McKenzie, Southington, Conn.; Mr. and Mrs. Michael Walsh,

Mrs. Edward L. Peene, Yonkers, N. Y.; Mrs. W. Paulison, Passaic, N. J.; Mrs. Alice W. Hatch, South Framingham; Mrs. J. P. Putnam, Westboro; Lawrence P. Stanton, Alden Webb, Beverly; Howard Smith, Mrs. G. W. F. Smith, Mrs. W. F. P. Sealy, G. W. F. Smith, Potsdam, N. Y.; Mr. and Mrs. Phil S. Smith, Montpelier, Vt.; Mrs. Mary C. G. Sprenkel, Mrs. Julia A. Sprenkel, Miss Louise Sprenkel, Miss Ella Sprenkel, York, Penn.; Mrs. C. W. Small, Portland, Me.; Mr. and Mrs. Harry F. Thomas, Saratoga Springs, N. Y.; Mrs. Wm. H. Thomas, Mrs. Harry L. Thomas, Hingham; Mrs. D. N. Tower, Cohasset; Mrs. John O. Fall, Quincy. — 129

SUMMARY OF ATTENDANCE.

Members	86
Representatives of Associates	33
Guests	129
	248
Counted twice	1
Total attendance	247

WEDNESDAY, SEPTEMBER 9.

The convention was called to order at 11 A.M. by President Charles K. Walker, who introduced Mayor James Cochrane of Montreal. The Mayor spoke as follows:

ADDRESS OF WELCOME BY MAYOR COCHRANE.

MAYOR COCHRANE. *Mr. President, Ladies and Gentlemen,*—It gives me great pleasure to welcome to our city so many people from the New England States, and especially to meet so many representatives of water works throughout your section. We do not receive you as strangers, although you come from the other side of the line, because we consider that there is really no difference between the two peoples. I suppose you have a great many important questions to discuss, and therefore it is not my intention to occupy your time by any speech. I will only say that you are heartily welcome to our city, and if any of you gentlemen should happen to get into any little trouble during your stay here, I hope you will feel at liberty to call upon the Mayor. [Laughter.] I hope that your deliberations will be successful, and that those connected with our water department may get some good ideas from you which will tend to improve our water supply. [Applause.]

RESPONSE BY PRESIDENT WALKER.

PRESIDENT WALKER. I wish to thank you, Mr. Mayor, in behalf of the Association, for the welcome which you have extended to us, and to assure you that we appreciate it. It has been in the air for a number of years that we were coming to Montreal, and now that we are here we think we are going to have a good time, and we trust that you will think more of us when we go away than you did when we came. [Applause.]

AMENDMENT TO THE CONSTITUTION.

MR. CHARLES W. SHERMAN. A circular was sent out with the notice of this meeting calling attention to a proposed amendment to the constitution, and giving the reasons therefor. The amendment proposed is as follows:

Strike out from Section 2 the following:

"Which shall include a subscription to the Journal of the New England Water Works Association."

Add a new section as follows:

"SECTION 4. — Three dollars of the dues of each member or associate, or such portion thereof as may be required, shall annually be applied to payment of a subscription to the Journal of the New England Water Works Association."

The reason for this, as explained in the circular, is to satisfy the postal authorities, and at the same time save a great deal of clerical work. I move the adoption of this amendment.

Adopted.

ENGINEERS' CLUB OF MONTREAL.

Secretary Kent read the following communication, extending to the members the privileges of the Engineers' Club of Montreal.

At the request of Mr. T. W. Lesage the chairman and members of the committee of the Engineers' Club have the honor to extend to Mr. Willard Kent and members of the New England Water Works Association the privilege of the club-house for two weeks.

C. DE B. LEPROHON, *Secretary.*

On motion of Mr. Sherman, a vote of thanks was tendered to the Engineers' Club of Montreal for their invitation.

THE ST. LOUIS EXPOSITION.

Secretary Kent read the following communication from the committee of the American Society of Civil Engineers on the Universal Exposition to be held in St. Louis in 1904.

St. Louis, Mo., U. S. A., August 24, 1903.

To the New England Water Works Association,
Boston, Mass.:

The American Society of Civil Engineers has appointed the above-named Committee to represent it at the Universal Exposition to be held at St. Louis in 1904, to commemorate the Louisiana Purchase.

It is the purpose of this committee to collect and present an exhibit of plans, photographs, models, and descriptions of American engineering works, principally work designed by members of the American Society, which it is believed will be of great interest both to laymen and engineers. It is intended also to make the headquarters of the society, which will be in the Liberal Arts Building, a center of information as to other exhibits in the exposition which may be of engineering interest. There will also be a register which will help one to find and meet his friends, and it is hoped that the headquarters may serve as a rallying point and rendezvous for all visiting engineers.

The members of the New England Water Works Association are cordially invited to avail themselves of the conveniences to be provided by our society during their visit to St. Louis and the exposition, and it is hoped that a large proportion of them will be able to do so.

By order of the Committee,
H. J. Pfeifer, *Secretary*.

On motion of Mr. Fels, it was voted to extend the thanks of the Association to the American Society of Civil Engineers for their communication and to accept their invitation.

NEW MEMBERS ELECTED.

The Secretary read the following names of applicants for membership, all of whom were duly recommended by the Executive Committee.

For Resident Member.

J. J. Desmond, Lawrence, Mass., President Water Board; C. Dwight Sharpe, Putnam, Conn., Superintendent Putnam Water Works; George S. Brown, Danielson, Conn., Superintendent; Tyler H. Bird, Belfast, Me., Engineer, Superintendent and Collector, Belfast Water Company; Bernon E. Helme, Kingston, R. I., Managing owner water supply for village of Kingston; Phil S. Smith, Montpelier, Vt., Superintendent Montpelier Water Department; Charles H. Johnson, Exeter, N. H.; Joseph M. Birmingham, Hartford, Conn., President Board of Water Commissioners; Fred D. Berry, Hartford, Conn., Secretary Board of Water Commissioners; Jesse M. Shaw, Hingham, Mass., inspector and collector for Hingham Water Co.; T. Howard Barnes, C. E., Medford, Mass.; Harvey D. Eaton, Waterville, Me.; A. M. French, Holyoke, Mass., Water Commissioner.

For Non-Resident Member.

H. R. C. Blagden, Alexandria, Egypt, Chief Engineer Alexandria Water Works; S. A. Stearns, Granite, Ill., Superintendent Water Works of Granite City, Madison, and Venice; W. H. Humphreys, York, England, Manager and Chief Engineer of York Water Works; A. E. Woodward, Wolverhampton, England, Chief Engineer Wolverhampton Water Works; Joseph D. Pointer, Palatka, Fla.; George Janin, Montreal, Canada, Superintendent Montreal Water Works; Thomas W. Lesage, Montreal, Canada, Assistant Superintendent Montreal Water Works; W. E. Lautz, Pekin, Ill., Secretary Pekin Water Works Co.

For Associate.

G. Schumacher, Second Vice-President New York Central Foundry Co., New York, manufacturers universal cast-iron water pipe; William M. Rea, Somerville, Mass., salesman, A. W. Chesterton Co.; Fred C. Gifford, Waltham, Mass.

On motion of Mr. Fuller the Secretary was instructed to cast one vote in favor of the applicants, which he did, and they were declared elected.

On motion of Mr. Sherman the President was requested to appoint a committee of five to nominate candidates for officers for the next year, and he subsequently named the following as the committee: Frank E. Merrill, F. W. Gow, A. E. Martin, T. G. Hazard, Jr., W. E. Hawks.

The afternoon session was occupied by a consideration of matters pertaining to the Montreal water supply. Mr. George Janin, superintendent of the Montreal Water Works, presented a paper giving a "History and Description of the Montreal Water Works." Following the reading of the paper, Mr. Hammond, Mr. Fred Brooks, Mr. Metcalf, Mr. Frank L. Fuller, Mr. Allen, Mr. Sherman, Mr. F. W. Dean, and others, asked questions which elicited from Mr. Janin and from Mr. Lesage, the assistant superintendent of the Montreal works, an elaboration of certain matters suggested by the paper.

Mr. T. W. Lesage followed with a paper entitled "Service Boxes of the Montreal Works."

In the evening, Mr. Frank L. Fuller, C.E., Boston, gave a description, illustrated by stereopticon views, of the work of

covering the Natick reservoir with a concrete roof. Mr. Leonard Metcalf opened the discussion which followed the reading of the paper, reviewing the recent developments in the use of the arch and modifications in the distribution of masonry in roofs. Mr. William B. Fuller spoke on the strength of the concrete groined arch, and Mr. F. W. Dean also participated in the discussion.

Mr. Henry Goldmark of the Canadian Pacific Railroad extended to the members of the Association an invitation to visit the extensive new locomotive and car shops of that road.

THURSDAY, SEPTEMBER 10.

At the morning session on Thursday, Mr. William R. Hill, chief engineer of the Croton Aqueduct Commission, read a paper prepared by Mr. John Venner, chief inspector, Bureau of Water, Syracuse, N. Y., on "Municipal Use and Waste of Water." The paper was discussed by Messrs. Harvey D. Eaton, Leonard Metcalf, Frank L. Fuller, F. W. Dean, and Kenneth Allen.

Mr. Charles W. Sherman presented a paper submitted in print by Mr. Frank C. Kimball, superintendent Knoxville Water Company, Knoxville, Tenn., entitled, "Some Six-Inch Meter Tests and How They Were Made." Mr. F. H. Crandall, who witnessed the tests as a member of the Committee on Private Fire Protection, gave his impressions from what he saw at Knoxville. On motion of Mr. Sherman it was voted to extend the privileges of the floor to any associates present representing meter companies, and in response to an invitation Mr. J. A. Tilden, who was present at Knoxville when the tests were made, spoke from the point of view of the meter manufacturers.

The next business was the consideration of the report of the Committee on Apportionment of Charges for Private Fire Protection and the Means of Controlling the Supply Thereto, which was presented by Mr. F. H. Crandall.

MR. CRANDALL. Your committee have conducted considerable correspondence and have had some meetings, and, as you all know,I was present at Knoxville and had opportunity to discuss the matter with Mr. Kimball, who is Mr. Wheeler's right-hand man, and I regard what Mr. Kimball said as practically what Mr. Wheeler said. Mr. Thomas of the committee and I are now

prepared to sign a report, but Mr. Wheeler is detained, for the same reason that Mr. Kimball is, in Knoxville.

I think it is time that this Association should give an expression of its opinion on this subject. I do not think it is necessary to wait for the development of different meters which are now on the market. An opinion can be expressed, and we have a report which we would like to make, and if you wish I will read it now. As I said a few minutes ago, there are devices which we hope may prove more satisfactory all around for the purpose of measuring water used for fire purposes than those at present on the market. There is one at present at the water-works station in Burlington, which will be tested in a short time by the maker, and if the test turns out as he hopes it will, and as we all hope it will, he will no doubt be glad to have later tests made by a committee of this Association. The report which we now have to make is as follows:

REPORT OF COMMITTEE ON APPORTIONMENT OF CHARGES FOR PRIVATE FIRE PROTECTION AND THE MEANS OF CONTROLLING THE SUPPLY THERETO.

Mr. President and Gentlemen of the New England Water Works Association, — Your Committee on Apportionment of Charges for Private Fire Protection and the Means of Controlling the Supply Thereto would respectfully report their findings, as follows:

A large part of the expense of furnishing private fire protection is on account of the cost of mains, reservoirs, conduits, pumping machinery, and other requirements of the service, in no wise dependent upon the amount of water used, and varying for different services approximately in proportion to the capacity designed to furnish the area protected, or the size of the service.

The cost of furnishing private fire service has also been found, owing to legitimate use and waste, always present, to a greater or less degree, to vary with the quantity of water used, in consequence of which the price, to some extent, should vary with the quantity used. The only way to accomplish this, and secure a reasonable control of private fire services, is by means of meter measurement, and a charge for such service, in the determination of which the extra cost of increased capacity of system required and value to the user should not be overlooked.

Except for the fact that, under certain conditions, the water company or department is liable not to receive sufficient compensation, on account of the inability of the meter to register correctly small streams, there are several meters suitable for this use, and with an increased demand for accurate measuring devices suitable for such purposes there are liable to be several more.

Set in a by-pass around a gate, accessible to any one to open, in case of fire, and which it shall be the duty of the water department to see opened, under such circumstances, meters, now on the market, can meet with no reasonable objection except from the water departments, and will probably meet but little from that source.

On every fire service, beside a gate for the exclusive use of the water department, which should be located as near the main as possible, there should be a cut-off back of all fixtures, so located as under any probable combination of circumstances to be conveniently accessible for the use of the premises.

No private fire line should be allowed larger than six inches in diameter, and this size only when, in the opinion of the superintendent or manager of the water department, such size is necessary on account of the size and situation of the property requiring the private fire line, provided, however, that no private fire line of any size should be permitted that will, when all available protection from such line is being utilized, reduce the normal pressure in the supplying main more than one-third.

The furnishing of private fire protection free, while charging a fixed rate for a smaller service, whether water be used from same or not, is creating an arbitrary distinction in favor of the one and against the other taxpayer, which cannot be justified as classification, in that it denies the essential impartial treatment guaranteed by the law to all citizens.

It matters not that the private fire-protected plant of a wealthy corporation is an advantage to the community, Inasmuch as it is an advantage to the corporation served and an expense to the water works, it should, by all the principles of common law and common honesty, bear its fair share of the expense incident to the service.

All of which is respectfully submitted,

F. H. CRANDALL,
R. J. THOMAS.

MR. J. W. GOODELL. For the purpose of bringing the matter before the Association, that a vote may be had upon it, I move that the report of the committee be accepted and adopted so far as made and the committee continued. I think it will be for the interests of the Association to continue the committee, so that it may obtain further material to be submitted to us at some later date. Adopted.

Mr. F. H. Pitcher, chief engineer of the Montreal Water & Power Co., Montreal, Canada, then submitted a paper entitled, "Pumping by Electricity."

ELECTION OF MEMBERS.

W. C. Leitch, Superintendent Montreal Water & Power Co., and F. K. Bixbie, Superintendent Water Works, Lindsay, Ontario, were elected non-resident members.

At the afternoon session, Mr. M. F. Collins, Superintendent of Water Works, Lawrence, Mass., gave a description, illustrated by stereopticon views, of the filter plant at Lawrence; and the Hon. John O. Hall of Quincy, Mass., read a paper entitled, "The Reciprocal Obligation of the Management of a Water Supply and the Community." The President and Mr. F. H. Crandall spoke upon matters suggested by the paper.

At the opening of the evening session, Mr. Henry F. Jenks, for the Committee on Exhibits, reported that the exhibitors had been as follows:

1. Pittsburg Meter Co., Pittsburg, Ga., Keystone Meters.
2. Ross Valve Co., Troy, N. Y., Reducing Valves, Water Engines and Filters.
3. Hersey Mfg. Co., South Boston, Mass., Water Meters and Water Works Appliances.
4. A. W. Chesterton & Co., Boston, Mass., Steam Packings and Engineers' Supplies.
5. Thomson Meter Co., Brooklyn, N. Y., Samples of Lambert Water Meters and also the Lambert Typewriter.
6. Ashton Valve Co., Boston, Mass., Safety Valves, Pressure Gages, Water Gages, and Steam Whistles.
7. Lamb & Ritchie, Cambridgeport, Mass., Tin-Lined and Lead-Lined Pipe.
8. Union Water Meter Co., Worcester, Mass., Water Meters.
9. H. Mueller Mfg. Co., Decatur, Ill., Water Main Tapping Machine and Water Works Appliances.
10. Lead-Lined Iron Pipe Co., Wakefield, Mass., Lead and Tin-Lined Pipe and Fittings.
11. Neptune Meter Co., Long Island City, N. Y., Trident and Crescent Meters.
12. Central Foundry Co., New York City, New Water Pipe; Joints Made without Packing.
13. Greenwood & Daggett Co., Boston, Mass., Steam Packing.
14. Henry R. Worthington, Meters.

ELECTION OF MEMBERS.

Mr. James Laurin, Civil Engineer, Montreal, was elected a non-resident member.

Mr. Leonard Metcalf of Boston gave a very interesting descrip-

tion, illustrated by lantern slides, of a trip across Porto Rico. Frederick Brooks, C.E., of Boston, spoke on "The Folly of Reckoning by Gallons which Differ Widely in Canada and the United States, while Both Countries Have Identical Liters and Cubic Meters."

The report of the Committee on Uniform Statistics being called for, Mr. Joseph E. Beals, chairman of the committee, said that it had none to make.

MR. LEONARD METCALF. It seems to me that the work of this committee is not quite complete, and I would move that it be continued. This question of uniform statistics is coming up in various ways; I might refer particularly to a general system of municipal accounting, and I think it might be of advantage to the Association to continue the committee in existence so it may recommend such action as would seem to be wise for the Association to take in any such direction.

MR. KENT. I think it was the understanding when the committee was appointed that it should be continued indefinitely, or at least for a long time. Isn't that so, Mr. Sherman?

MR. CHARLES W. SHERMAN. At the time we were continued last year the committee had reported the changes that we thought desirable in the standard form of summarizing statistics, and suggested that a form for summarizing purification statistics ought to be prepared, but that we had not at that time been able to prepare such a summary, although we had done some work towards it, and we asked to be continued with authority to try the form that we should draw up. The preparation of such a temporary or experimental form of statistics of purification works was left to a sub-committee, consisting of Mr. Baker and myself. Neither of us has done anything on the matter. We still have some hopes that such a schedule may be prepared, although I confess that at the present moment the hope is not so sanguine as it formerly was. There is, however, a possibility, as Mr. Metcalf has suggested, that in these days of the consideration of uniform municipal accounting and other matters of that sort by various organizations, not merely water-works organizations, but others having municipal matters in consideration, some questions may come up where consideration by committees of different societies would be desirable, and consequently there might be something

gained, outside of the possible formulation of the schedule of purification statistics, by having the committee continued. At any rate, we cannot do any less than we have done the past year, and certainly no harm can be done.

Mr. Metcalf's motion to continue the committee was adopted, and the convention then adjourned.

November Meeting.

Hotel Brunswick,
Boston, November 11, 1903.

President Charles K. Walker in the chair.

The following members and guests were present:

Members.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, T. H. Barnes, J. E. Beals, George Bowers, Dexter Brackett, E. C. Brooks, Fred. Brooks, G. A. P. Bucknam, L. Z. Carpenter, George Cassell, G. F. Chace, J. C. Chase, F. C. Coffin, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, J. W. Crawford, G. E. Crowell, F. W. Dean, A. O. Doane, G. E. Evans, B. R. Felton, C. R. Felton, J. N. Fergerson, J. A. Fitch, W. E. Foss, A. D. Fuller, F. L. Fuller, W. B. Fuller, H. F. Gibbs, Albert S. Glover, J. O. Hall, J. D. Hardy, L. M. Hastings. V. C. Hastings, T. G. Hazard, Jr., D. A. Heffernan, H. G. Holden, W. E. Johnson, E. W. Kent, Willard Kent, G. A. King, A. A. Knudson, C. F. Knowlton, E. S. Larned, F. A. McInnes, H. V. Macksey, W. E. Maybury, F. E. Merrill, Leonard Metcalf, F. L. Northrop, W. H. Richards, W. W. Robertson, E. M. Shedd, E. W. Shedd, J. H. Shedd, C. W. Sherman, H. O. Smith, G. H. Snell, G. A. Stacy, G. T. Staples, J. T. Stevens, J. J. Sullivan, C. N. Taylor, R. J. Thomas, H. L Thomas, W. H. Thomas, J. L. Tighe, G. W. Travis, W. H. Vaughn, C. K. Walker, R. S. Weston, J. C. Whitney, W. P. Whittemore, G. E. Wilde, F. I. Winslow, G. E. Winslow. — 79.

Associates.

Builders' Iron Foundry, by Frederick N. Connet; Chapman Valve Mfg. Co., by Edward F. Hughes; Charles A. Claflin & Co., by Charles A. Claflin; Coffin Valve Co., by H. L. Weston; Garlock Packing Co., by Edward N. Corning; Greenwood & Daggett Co., by W. H. Greenwood; Hersey Mfg. Co., by Albert S. Glover, James A. Tilden, and Walter A. Hersey; Henry F. Jenks; Lead-Lined Iron Pipe Co., by T. E. Dwyer; H. Mueller Mfg. Co., by W. L. Dickel; National Meter Co., by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Co., by W. H. Van Winkle and H. H. Kinsey; Perrin, Seamans & Co., by James C. Campbell; Rensselaer Mfg. Co., by Fred S. Bates; Sumner & Goodwin Co., by H. A. Gorham; Sweet & Doyle, by H. L. DeWolfe; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by F. L. Northrop; United States Cast Iron Pipe & Foundry Co., by Wm. B. Franklin. — 23.

GUESTS.

Randolph T. Ode, Providence Engineering Works, Providence, R. I.; Frank L. Weaver and R. J. Crowley, Water Commissioners, Lowell, Mass.; E. M. Peck, Engineer, Hartford, Conn.; R. E. Walsh, Water Registrar, Woburn, Mass.; Albert F. Hill, Superintendent Pawtuxet Valley Water Co., Phenix, R. I. — 6.

The following named were elected resident members:

William T. Barnes, Boston, Hydraulic and Sanitary Engineer; Ennan Miland Peck, West Hartford, Conn., Distribution Engineer of the Hartford Water Works; Albert F. Hill, Phenix, R. I., Superintendent of the Pawtuxet Valley Water Works Company.

Mr. J. Herbert Shedd then presented a paper entitled, "Requisite Amount of Water for Public Supply." A long discussion followed, which was participated in by Messrs. Holden, Winslow, Hastings, Chace, Taylor, Albert F. Hill, Larned, Richards, Coggeshall, Robertson, Robert J. Thomas, Edwin C. Brooks, Connet, Brackett, Foster, and Dean.

Mr. Francis W. Dean presented a paper entitled "Pumping Engines."

Adjourned.

EXECUTIVE COMMITTEE.

The Executive Committee met at headquarters, Tremont Temple, at 12 M., November 11, 1903, Vice-President Brooks in the chair, and present, also, Messrs. Willard Kent, E. W. Kent, L. M. Bancroft, G. A. Stacy and C. W. Sherman. Three applications for membership were considered, and it was voted to recommend the applicants to the Association for election.

Adjourned.

WILLARD KENT, *Secretary.*